Project Details

Project Name: MTSOLAR_842CGDAJ3LHI

Location: 703 SW Persels Rd, Lee's Summit, MO 64081, USA

Unique ID: 4P-19.75-8TOP-XD-45-L-4Hx10W-1B2D

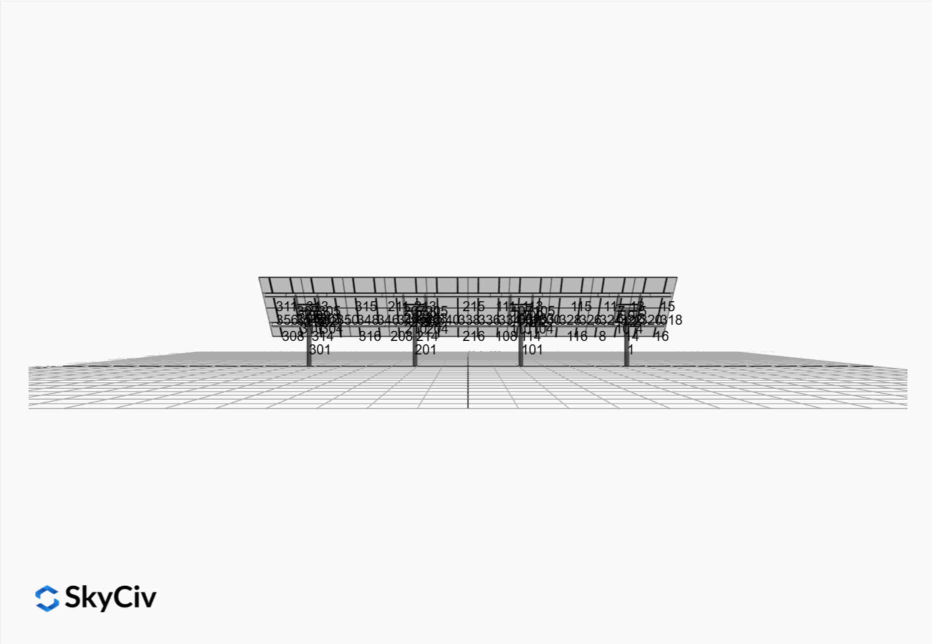
Dealer: ______________________________

Date: Fri Sep 26 2025

Number of Modules: 40

Number of Poles: 4

Date Sold: ______________________________



Array Dimensions N/S	15.03 ft
Array Dimensions E/W	75.58 ft
Winter Tilt Angle	46
Front Edge Clearance	5 ft

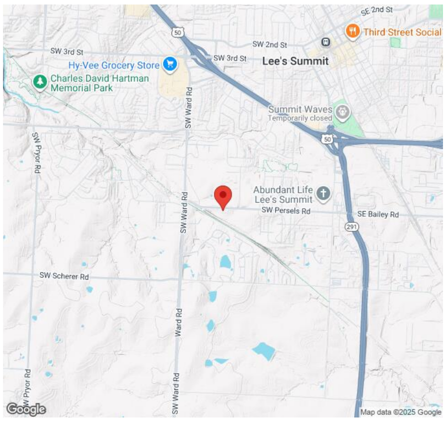
MT Solar Bill of Materials (4P-19.75-8TOP-XD-45-L-4Hx10W-1B2D)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-45	45IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-HOOK-4PK	Hook Clamp	10

Rail Bill of Materials

Part	Qty
Rails (180in)	20
Rail Attachment	40
Module Mid Clamp	60
Module End Clamp	40
Ground Lug	10

Site Details:



Site Address: 703 SW Persels Rd, Lee's Summit, MO 64081, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	89.70in
Number of Rows:	4
Number of Columns:	10
Total Number of Modules:	40
Winter Tilt Angle:	46
Front Edge Clearance:	5
Total Array Height at Tilt:	15.81 ft
Total Frame Length:	74.25 ft
Module Info/Notes:	Axitek 580 w bifacial
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	75.58 ft
Rail Length:	180.40 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	10.41 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.50 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 6.50 ft
Foundation Volume:	15.704 y^3

Site Info

Risk Category:	I
Exposure:	D
Soil Classification:	sand
Site Location:	703 SW Persels Rd, Lee's Summit, MO 64081, USA
Wind Speed:	104 mph

Snow Load:	20 psf

Design Disclaimer

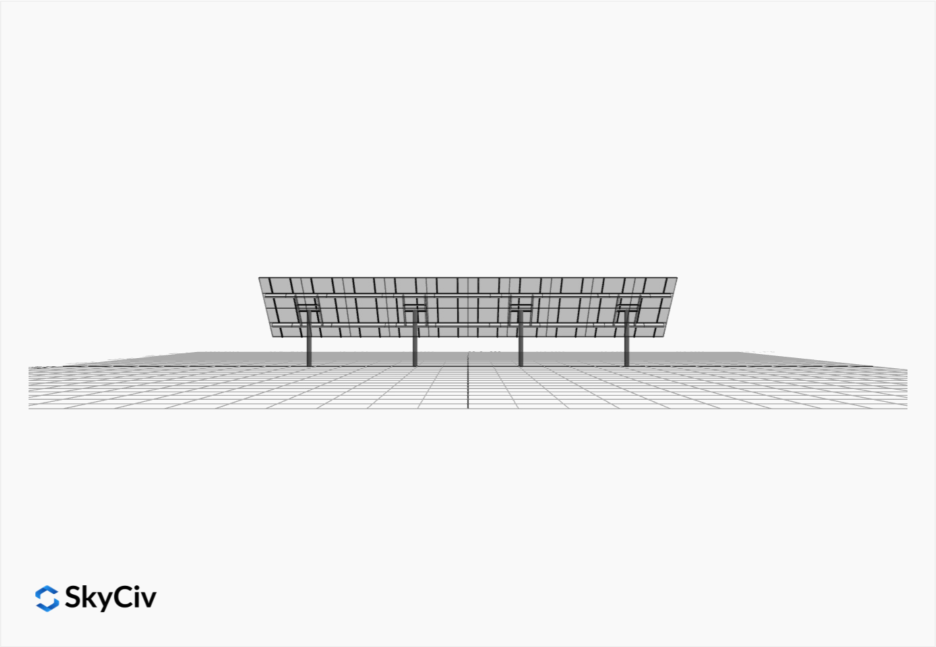
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

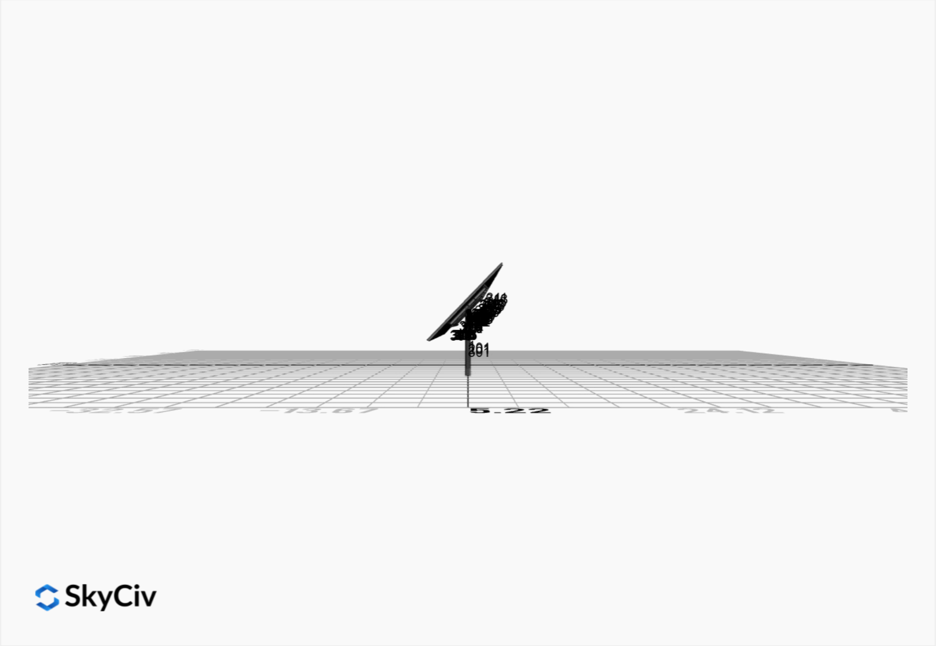
AutoDesigner Input

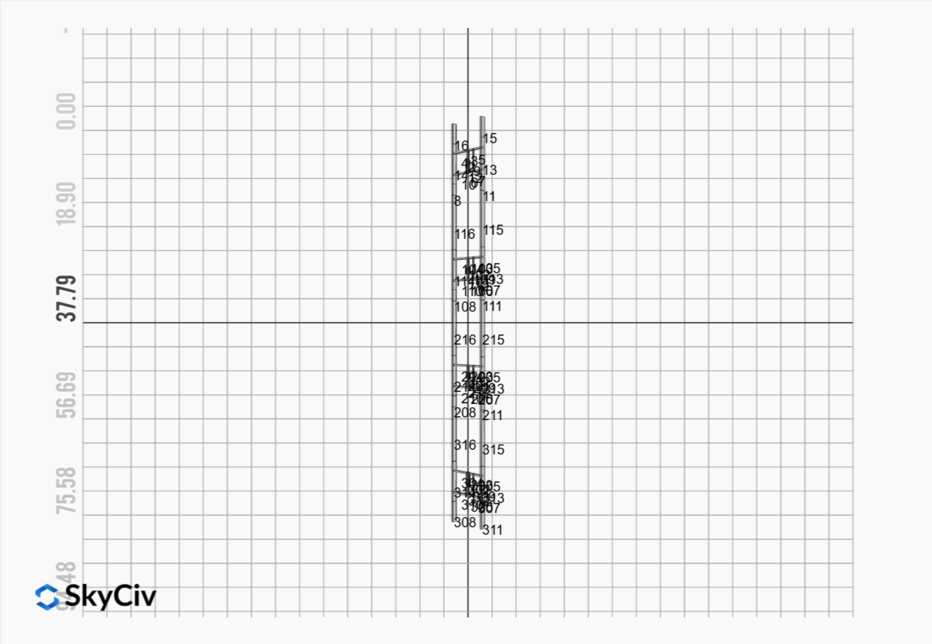
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"John Spencer","designer_email":"c4lsfd@gmail.com","designer_phone":"8168967204","project_id":"MTSOLAR_842CGDAJ3LHI","site_address":"703 SW Persels Rd, Lee's Summit, MO 64081, USA","module_info":"Axitek 580 w bifacial","module_width":44.6,"module_length":89.7,"number_rows":"4","number_columns":10,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":46,"ground_clearance":5,"risk_category":"I","exposure_category":"D","frame_duty_override":"XD","pole_override":"8_40","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

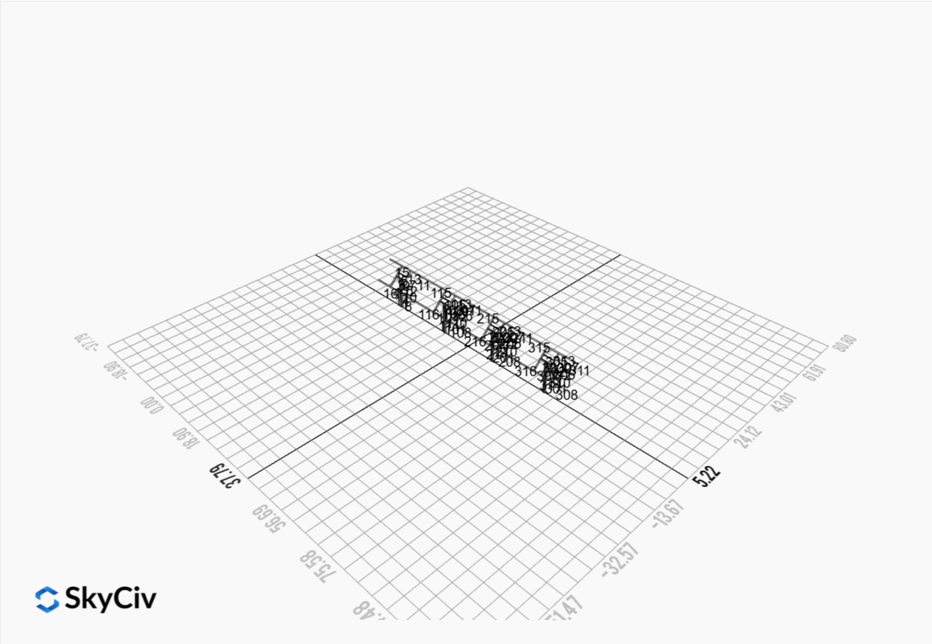
Design Notes:

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






0.00
18.90
37.79
56.69
75.58
SkyCiv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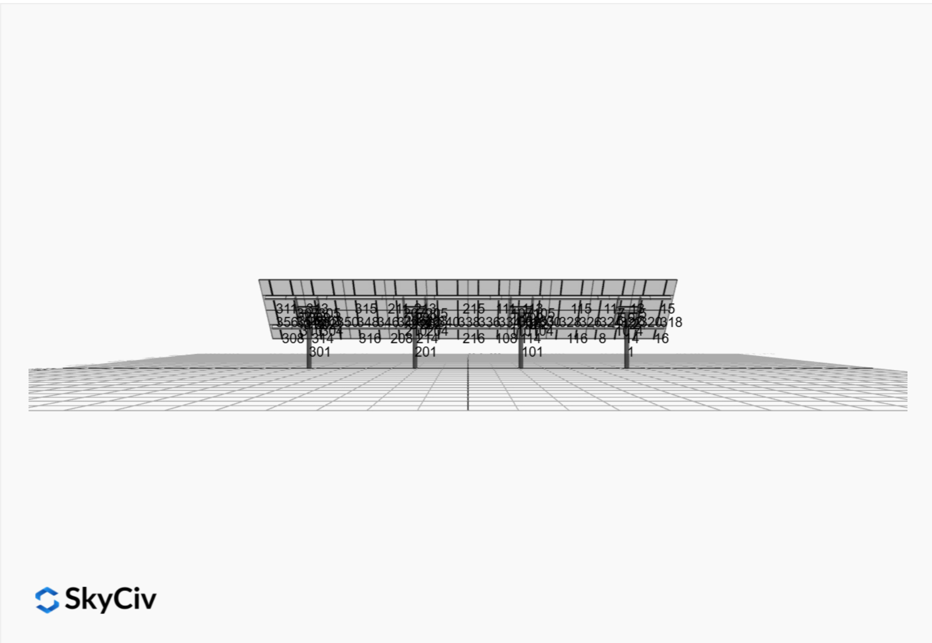
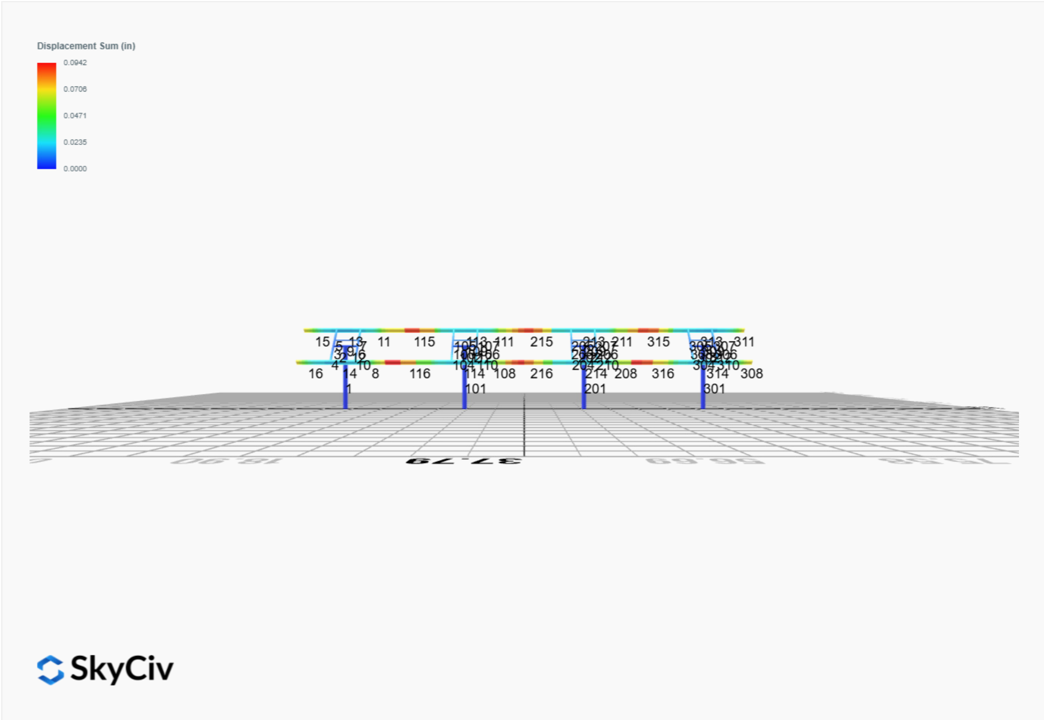
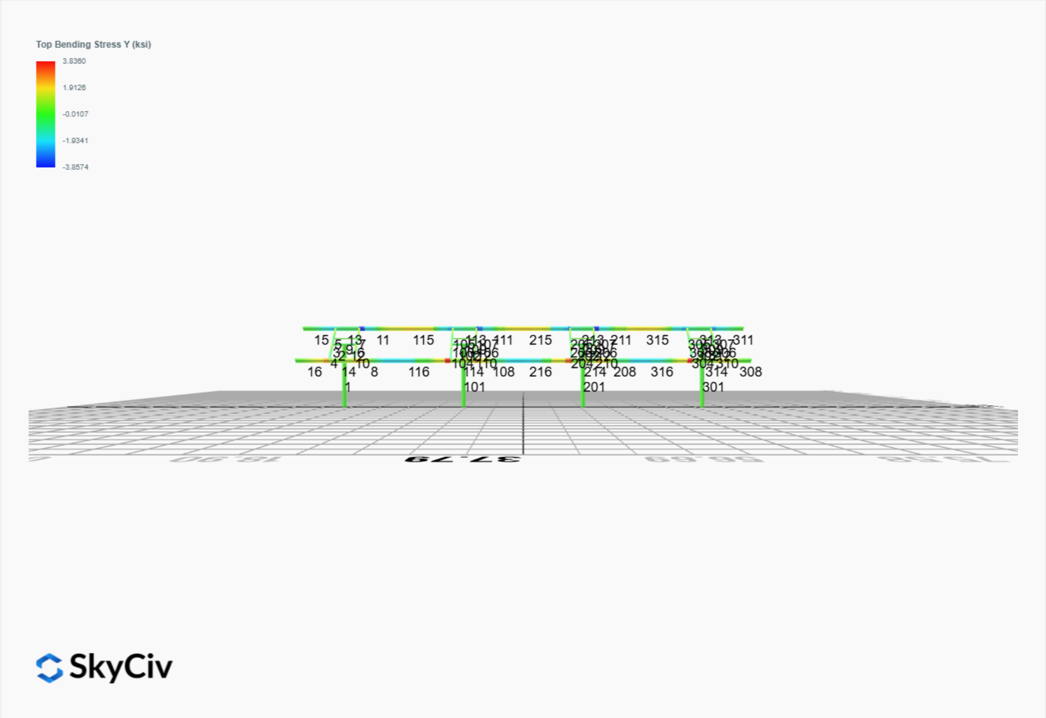
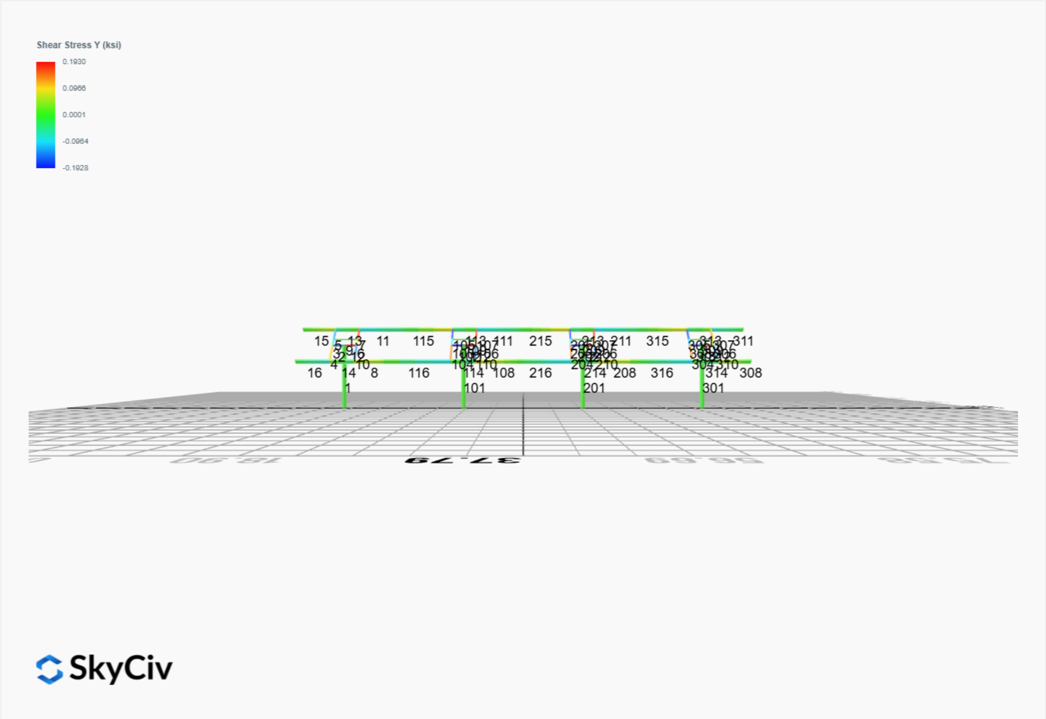
SkyCiv

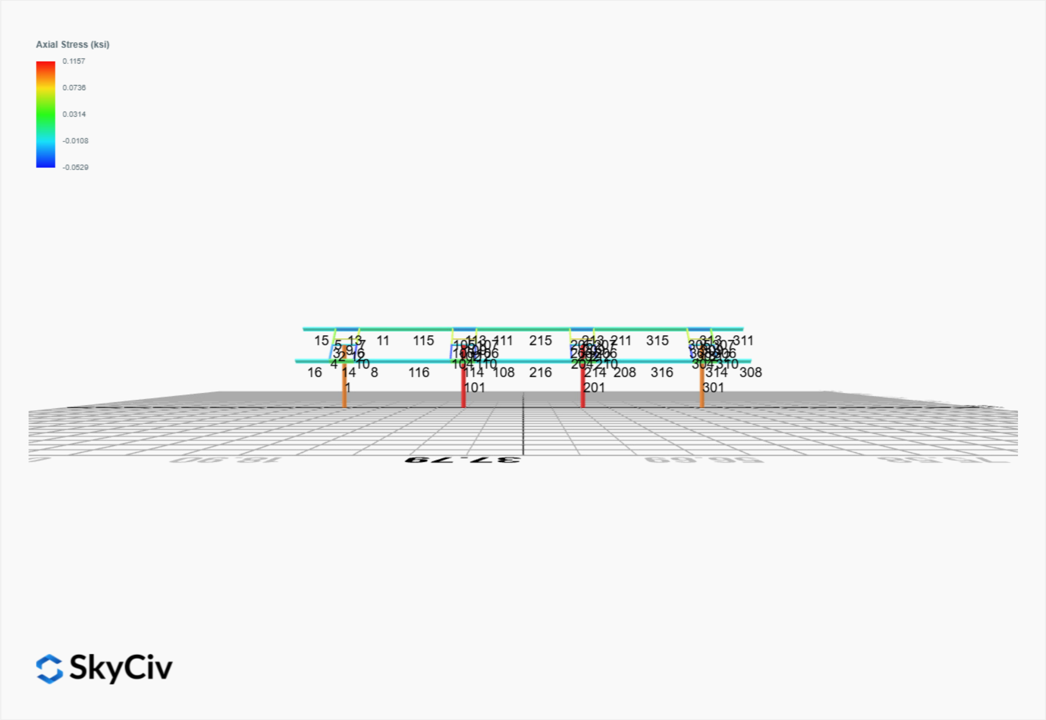

SkyCiv

FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
3.8360
1.9126
-0.0107
-1.9341
-3.8574
SkyCiv


Shear Stress Y (ksi)
0.1930
0.0966
0.0001
-0.0964
-0.1928
SkyCiv



Axial Stress (ksi)
0.1157
0.0736
0.0314
-0.0108
-0.0529
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	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 2. D + L	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 3. D + (S or Lr or R)	0.0119	3.0296	0.0406	0.1262	-0.0155	-0.0908
ULS: 3. D + (S or Lr or R)	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0108	2.8179	0.0371	0.1153	-0.0141	-0.0809
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 5b. D + 0.7E	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0108	2.8179	0.0371	0.1153	-0.0141	-0.0809
ULS: 8. 0.6D + 0.7E	0.0047	1.3096	0.0160	0.0496	-0.0060	-0.0309
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7203	4.7981	0.1079	0.3136	-0.3352	28.7797
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7341	-0.4320	-0.0528	-0.1427	0.3081	-28.2422
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0352	4.7795	0.0981	0.2886	-0.2580	21.5424
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0108	2.8179	0.0371	0.1153	-0.0141	-0.0809
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0556	0.8569	-0.0225	-0.0537	0.2245	-21.2241
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0108	2.8179	0.0371	0.1153	-0.0141	-0.0809
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0383	4.1443	0.0876	0.2558	-0.2539	21.5719
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0525	0.2216	-0.0330	-0.0864	0.2286	-21.1945
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0078	2.1826	0.0266	0.0826	-0.0100	-0.0514
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7234	3.9251	0.0973	0.2805	-0.3312	28.8003
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0047	1.3096	0.0160	0.0496	-0.0060	-0.0309
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7310	-1.3051	-0.0635	-0.1757	0.3121	-28.2217
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0047	1.3096	0.0160	0.0496	-0.0060	-0.0309

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.4024
Shear X	-4.5561
Shear Z	0.1754
Moment X	0.5088
Moment Y (Twist)	0.5602
Moment Z	48.3834

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	4.7981
Shear X	-2.7341
Shear Z	0.1079
Moment X	0.3136
Moment Y (Twist)	0.3352
Moment Z	28.8003

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	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 2. D + L	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 3. D + (S or Lr or R)	-0.0118	3.3923	-0.0024	-0.0077	0.0074	0.1405
ULS: 3. D + (S or Lr or R)	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0107	3.1494	-0.0022	-0.0071	0.0068	0.1303

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 5b. D + 0.7E	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0107	3.1494	-0.0022	-0.0071	0.0068	0.1303
ULS: 8. 0.6D + 0.7E	-0.0046	1.4523	-0.0009	-0.0030	0.0029	0.0598
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0966	5.4221	0.0114	0.0296	-0.0607	32.5197
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0829	-0.5822	-0.0134	-0.0367	0.0658	-31.5532
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3275	5.4006	0.0075	0.0190	-0.0424	24.4452
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0107	3.1494	-0.0022	-0.0071	0.0068	0.1303
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3072	0.8974	-0.0110	-0.0308	0.0525	-23.6094
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0107	3.1494	-0.0022	-0.0071	0.0068	0.1303
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3244	4.6717	0.0081	0.0210	-0.0443	24.4147
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3103	0.1685	-0.0104	-0.0288	0.0506	-23.6400
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0077	2.4204	-0.0015	-0.0051	0.0048	0.0997
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0935	4.4539	0.0120	0.0317	-0.0627	32.4798
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0046	1.4523	-0.0009	-0.0030	0.0029	0.0598
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0860	-1.5504	-0.0127	-0.0346	0.0639	-31.5931
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0046	1.4523	-0.0009	-0.0030	0.0029	0.0598

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	8.3928
Shear X	-5.1585
Shear Z	-0.0225
Moment X	-0.0615
Moment Y (Twist)	0.1112
Moment Z	54.6622

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.4221
Shear X	-3.0966
Shear Z	-0.0134
Moment X	-0.0367
Moment Y (Twist)	0.0658
Moment Z	32.5197

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	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 2. D + L	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 3. D + (S or Lr or R)	-0.0122	3.3931	0.0029	0.0082	-0.0066	0.1443
ULS: 3. D + (S or Lr or R)	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0111	3.1500	0.0027	0.0075	-0.0061	0.1337
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 5b. D + 0.7E	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0111	3.1500	0.0027	0.0075	-0.0061	0.1337
ULS: 8. 0.6D + 0.7E	-0.0048	1.4525	0.0011	0.0032	-0.0026	0.0613
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0984	5.4243	-0.0107	-0.0308	0.0577	32.5366
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.0842	-0.5834	0.0134	0.0384	-0.0617	-31.5646
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022

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	-2.3289	5.4025	-0.0068	-0.0196	0.0404	24.4595
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0111	3.1500	0.0027	0.0075	-0.0061	0.1337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3080	0.8968	0.0113	0.0323	-0.0491	-23.6164
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0111	3.1500	0.0027	0.0075	-0.0061	0.1337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3258	4.6734	-0.0075	-0.0217	0.0422	24.4280
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3111	0.1677	0.0106	0.0301	-0.0474	-23.6479
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0080	2.4209	0.0019	0.0054	-0.0043	0.1022
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0952	4.4559	-0.0115	-0.0329	0.0594	32.4957
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0048	1.4525	0.0011	0.0032	-0.0026	0.0613
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.0873	-1.5518	0.0127	0.0362	-0.0600	-31.6055
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0048	1.4525	0.0011	0.0032	-0.0026	0.0613

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	8.3963
Shear X	-5.1613
Shear Z	0.0226
Moment X	0.0645
Moment Y (Twist)	0.1044
Moment Z	54.6903

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.4243
Shear X	-3.0984
Shear Z	0.0134
Moment X	0.0384
Moment Y (Twist)	0.0617
Moment Z	32.5366

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	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 2. D + L	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 3. D + (S or Lr or R)	0.0121	3.0293	-0.0412	-0.1289	0.0127	-0.0927
ULS: 3. D + (S or Lr or R)	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0110	2.8176	-0.0376	-0.1178	0.0115	-0.0827
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 5b. D + 0.7E	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0110	2.8176	-0.0376	-0.1178	0.0115	-0.0827
ULS: 8. 0.6D + 0.7E	0.0047	1.3094	-0.0162	-0.0506	0.0049	-0.0316
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7195	4.7972	-0.1086	-0.3185	0.3326	28.7721
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7336	-0.4315	0.0528	0.1440	-0.3090	-28.2374
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0345	4.7787	-0.0988	-0.2934	0.2548	21.5359
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0110	2.8176	-0.0376	-0.1178	0.0115	-0.0827
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0553	0.8571	0.0222	0.0535	-0.2263	-21.2212
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0110	2.8176	-0.0376	-0.1178	0.0115	-0.0827
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0376	4.1435	-0.0882	-0.2600	0.2515	21.5659
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0521	0.2220	0.0328	0.0869	-0.2297	-21.1912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0079	2.1824	-0.0270	-0.0844	0.0082	-0.0527

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7226	3.9243	-0.0978	-0.2848	0.3293	28.7932
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0047	1.3094	-0.0162	-0.0506	0.0049	-0.0316
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7304	-1.3045	0.0635	0.1778	-0.3123	-28.2163
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0047	1.3094	-0.0162	-0.0506	0.0049	-0.0316

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.4009
Shear X	-4.5552
Shear Z	-0.1764
Moment X	-0.5168
Moment Y (Twist)	0.5561
Moment Z	48.3715

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	4.7972
Shear X	-2.7336
Shear Z	-0.1086
Moment X	-0.3185
Moment Y (Twist)	0.3326
Moment Z	28.7932

Project Details

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

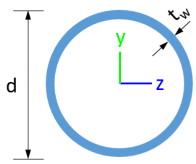
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

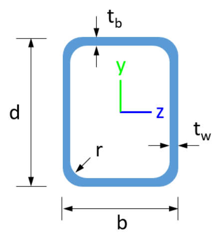
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

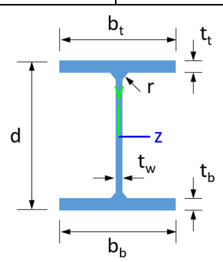
Section Dimensions



ID	Name	d (in)	t_w (in)
3	2in Pipe Sch 120	2.38	0.25
6	4in Pipe Sch 120	4.50	0.44
9	8in Pipe Sch 40	8.63	0.32



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



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

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

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	21.85	21.85	10.41	-	300	200	1
2	6	2.00	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.15,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
4	17	2.44	2.44	3.75	1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.68,1.62,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
8	20	1.33	1.33	2.05	1.66,1.66,1.66,1.66,1.66,1.66,1.64,1.66,1.62,1.66,1.64,1.66,1.63,1.66,1.64,1.66,1.56,1.66,1.64,1.66,1.61,1.66,1.63,1.66,1.63,1.66	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
11	20	1.33	1.33	2.05	1.69,1.69,1.69,1.69,1.69,1.69,1.78,1.69,1.84,1.69,1.79,1.69,1.83,1.69,1.76,1.69,2.08,1.69,1.77,1.69,1.90,1.69,1.79,1.69,1.82,1.69	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.11,1.11,1.07,1.11,1.11,1.11,1.09,1.11,1.10,1.11,1.10,1.11	300	200	1
14	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11	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	9	21.85	21.85	10.41	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.15,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
105	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
106	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
108	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.07,2.06,2.07,2.06,2.07,2.06,2.07,2.06,2.07,1.85,2.07,2.06,2.07,2.05,2.07,2.06,2.07,2.06,2.07	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
111	20	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,1.76,2.06,1.62,2.06,1.75,2.06,1.64,2.06,1.84,2.06,1.33,2.06,1.80,2.06,1.54,2.06,1.74,2.06,1.66,2.06	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.06,1.05,1.05,1.05,1.15,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.06,1.05	300	200	1
114	20	4.88	4.00	7.50	1.04,1.04,1.04,1.05,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.06,1.04,1.05,1.05,1.08,1.05,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
115	20	10.20	10.20	10.20	1.19,1.19,1.19,1.19,1.19,1.19,1.16,1.19,1.15,1.19,1.16,1.19,1.15,1.19,1.17,1.19,1.09,1.19,1.17,1.19,1.14,1.19,1.16,1.19,1.15,1.19	300	200	1
116	20	10.20	10.20	10.20	1.20,1.20,1.20,1.20,1.20,1.20,1.19,1.20,1.19,1.20,1.19,1.20,1.19,1.20,1.19,1.20,1.18,1.20,1.19,1.20,1.19,1.20,1.19,1.20,1.19,1.20	300	200	1
201	9	21.85	21.85	10.41	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
205	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
206	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.15,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
208	20	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,2.02,2.06,1.97,2.06,2.02,2.06,1.98,2.06,2.05,2.06,1.78,2.06,2.03,2.06,1.94,2.06,2.02,2.06,1.99,2.06	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
211	20	1.33	1.33	2.05	2.03,2.04,2.03,2.04,2.03,2.03,1.67,2.04,1.54,2.04,1.66,2.03,1.56,2.03,1.74,2.04,1.26,2.04,1.70,2.03,1.46,2.03,1.65,2.03,1.58,2.03	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.06,1.05,1.06,1.05,1.06,1.05,1.05,1.05,1.14,1.05,1.05,1.05,1.07,1.05,1.06,1.05,1.06,1.05	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.05,1.04,1.05,1.04,1.05,1.04,1.05,1.04,1.08,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
215	20	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.13,1.16,1.14,1.16,1.14,1.16,1.15,1.16,1.10,1.16,1.15,1.16,1.13,1.16,1.14,1.16,1.14,1.16	300	200	1
216	20	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17	300	200	1
301	9	21.85	21.85	10.41	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
304	17	2.44	2.44	3.75	1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
305	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
306	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.15,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
307	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	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	1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.68,1.62,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	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	2.00	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.10,1.11,1.11,1.11,1.07,1.11,1.10,1.11,1.09,1.11,1.10,1.11,1.10,1.11	300	200	1
314	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11	300	200	1

315	20	10.20	10.20	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.14,1.12,1.15,1.12,1.14,1.12,1.14,1.12,1.13,1.12,1.18,1.12,1.14,1.12,1.15,1.12,1.14,1.12,1.14,1.12	300	200	1
316	20	10.20	10.20	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	211.05	83.29	83.29	113.39	113.39
2	251.01	246.00	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	32.79	6.46	56.26	44.91
14	159.30	97.43	33.54	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	377.97	211.05	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.97	6.46	56.26	44.91
114	159.30	97.43	31.93	6.46	56.26	44.91
115	159.30	32.87	20.93	6.46	56.26	44.91
116	159.30	32.87	22.67	6.46	56.26	44.91
201	377.97	211.05	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.94	6.46	56.26	44.91
214	159.30	97.43	31.90	6.46	56.26	44.91
215	159.30	32.87	21.19	6.46	56.26	44.91
216	159.30	32.87	22.14	6.46	56.26	44.91
301	377.97	211.05	83.29	83.29	113.39	113.39
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	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	246.00	27.16	27.16	75.30	75.30
313	159.30	97.43	32.76	6.46	56.26	44.91
314	159.30	97.43	33.59	6.46	56.26	44.91
315	159.30	32.87	21.61	6.46	56.26	44.91
316	159.30	32.87	21.43	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	0.035	0.581	0.016	0.040	0.002	0.605	#13	0.446	Not Required	Pass
2	0.001	0.188	0.149	0.043	0.029	0.338	#13	0.055	Not Required	Pass
3	0.004	0.351	0.019	0.035	0.002	0.366	#13	0.046	Not Required	Pass
4	0.004	0.351	0.060	0.035	0.014	0.390	#13	0.082	Not Required	Pass
5	0.004	0.218	0.057	0.035	0.015	0.226	#13	0.076	Not Required	Pass
6	0.005	0.403	0.036	0.041	0.007	0.433	#13	0.046	Not Required	Pass
7	0.005	0.250	0.081	0.040	0.021	0.265	#13	0.076	Not Required	Pass
8	0.001	0.046	0.086	0.024	0.009	0.087	#23	0.102	Not Required	Pass
9	0.006	0.030	0.039	0.002	0.001	0.071	#13	0.206	Not Required	Pass
10	0.005	0.390	0.080	0.039	0.018	0.417	#13	0.082	Not Required	Pass
11	0.001	0.043	0.087	0.025	0.009	0.090	#23	0.102	Not Required	Pass
12	0.001	0.237	0.169	0.051	0.033	0.406	#13	0.036	Not Required	Pass
13	0.003	0.119	0.219	0.032	0.012	0.271	#21	0.306	Not Required	Pass
14	0.004	0.116	0.218	0.031	0.012	0.262	#21	0.204	Not Required	Pass
15	0.000	0.034	0.075	0.015	0.006	0.098	#21	Not Required	Not Required	Pass
16	0.000	0.034	0.075	0.015	0.006	0.098	#21	Not Required	Not Required	Pass
101	0.040	0.656	0.002	0.045	0.000	0.677	#13	0.446	Not Required	Pass
102	0.001	0.238	0.179	0.053	0.034	0.418	#13	0.036	Not Required	Pass
103	0.005	0.420	0.031	0.042	0.005	0.445	#13	0.046	Not Required	Pass
104	0.005	0.428	0.079	0.043	0.017	0.472	#13	0.082	Not Required	Pass
105	0.005	0.260	0.081	0.041	0.021	0.275	#13	0.076	Not Required	Pass
106	0.005	0.430	0.031	0.043	0.005	0.453	#13	0.046	Not Required	Pass
107	0.005	0.267	0.078	0.043	0.020	0.282	#13	0.076	Not Required	Pass
108	0.002	0.035	0.081	0.025	0.009	0.093	#21	0.102	Not Required	Pass
109	0.007	0.031	0.033	0.001	0.000	0.066	#13	0.206	Not Required	Pass
110	0.005	0.430	0.076	0.043	0.017	0.468	#13	0.082	Not Required	Pass

111	0.001	0.043	0.083	0.025	0.009	0.090	#21	0.102	Not Required	Pass
112	0.001	0.244	0.183	0.054	0.035	0.427	#13	0.036	Not Required	Pass
113	0.003	0.111	0.220	0.032	0.012	0.287	#21	0.306	Not Required	Pass
114	0.005	0.129	0.219	0.033	0.012	0.296	#21	0.306	Not Required	Pass
115	0.005	0.177	0.116	0.025	0.009	0.262	#13	0.780	Not Required	Pass
116	0.003	0.169	0.117	0.026	0.009	0.255	#13	0.780	Not Required	Pass
201	0.040	0.657	0.002	0.046	0.000	0.677	#13	0.446	Not Required	Pass
202	0.001	0.244	0.183	0.054	0.035	0.427	#13	0.036	Not Required	Pass
203	0.005	0.430	0.031	0.043	0.005	0.453	#13	0.046	Not Required	Pass
204	0.005	0.430	0.076	0.043	0.017	0.468	#13	0.082	Not Required	Pass
205	0.005	0.267	0.079	0.043	0.020	0.282	#13	0.076	Not Required	Pass
206	0.005	0.421	0.031	0.042	0.005	0.445	#13	0.046	Not Required	Pass
207	0.005	0.260	0.081	0.042	0.021	0.275	#13	0.076	Not Required	Pass
208	0.001	0.038	0.088	0.026	0.009	0.098	#21	0.102	Not Required	Pass
209	0.007	0.031	0.033	0.001	0.000	0.067	#13	0.206	Not Required	Pass
210	0.005	0.429	0.079	0.043	0.017	0.472	#13	0.082	Not Required	Pass
211	0.001	0.046	0.088	0.025	0.009	0.094	#21	0.102	Not Required	Pass
212	0.001	0.239	0.179	0.053	0.034	0.418	#13	0.036	Not Required	Pass
213	0.003	0.111	0.220	0.032	0.012	0.288	#21	0.306	Not Required	Pass
214	0.005	0.129	0.219	0.033	0.012	0.296	#21	0.306	Not Required	Pass
215	0.006	0.178	0.117	0.025	0.009	0.263	#13	0.780	Not Required	Pass
216	0.004	0.157	0.118	0.025	0.009	0.244	#13	0.780	Not Required	Pass
301	0.035	0.581	0.016	0.040	0.002	0.605	#13	0.446	Not Required	Pass
302	0.001	0.237	0.169	0.051	0.033	0.406	#13	0.036	Not Required	Pass
303	0.005	0.403	0.036	0.041	0.007	0.433	#13	0.046	Not Required	Pass
304	0.005	0.390	0.080	0.039	0.018	0.416	#13	0.082	Not Required	Pass
305	0.005	0.250	0.081	0.040	0.021	0.265	#13	0.076	Not Required	Pass
306	0.004	0.351	0.019	0.035	0.002	0.366	#13	0.046	Not Required	Pass
307	0.004	0.217	0.057	0.035	0.015	0.226	#13	0.076	Not Required	Pass
308	0.000	0.034	0.075	0.015	0.006	0.098	#21	Not Required	Not Required	Pass
309	0.006	0.030	0.039	0.002	0.001	0.071	#13	0.206	Not Required	Pass
310	0.004	0.351	0.060	0.035	0.014	0.390	#13	0.082	Not Required	Pass
311	0.000	0.034	0.075	0.015	0.006	0.098	#21	Not Required	Not Required	Pass
312	0.001	0.188	0.149	0.043	0.029	0.337	#13	0.055	Not Required	Pass
313	0.003	0.119	0.219	0.032	0.012	0.271	#21	0.204	Not Required	Pass
314	0.004	0.116	0.218	0.031	0.012	0.261	#21	0.306	Not Required	Pass
315	0.005	0.181	0.116	0.025	0.009	0.264	#13	0.780	Not Required	Pass
316	0.003	0.178	0.116	0.024	0.009	0.261	#13	0.780	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis

KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

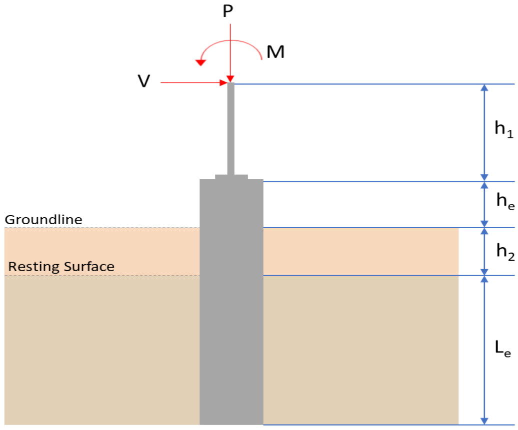
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.798	7.402
V_x (kip)	-2.734	-4.556
V_z (kip)	0.108	0.175
M_x (kipft)	0.314	0.509
M_z (kipft)	28.800	48.383

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,

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

$$H_o = \frac{(-2.734\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.43535\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.8 \text{ kipft}) + ((-2.734 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.586 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.9561 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.108 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.017197 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.314 \text{ kipft}) + ((0.108 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.05 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.8029 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.9561 \text{ ft}), (1.8029 \text{ ft})]$$

$$L_{e,req} = 5.956 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.956 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.91631$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.798\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.29988\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.29988\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.14994$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.43535\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.586\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.586\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.43535\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.586\ \mathrm{kipft/ft})) + (4 \times (-0.43535\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4912\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.586\ \mathrm{kipft/ft})) + (3 \times (-0.43535\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.586\ \mathrm{kipft/ft})) + (2 \times (-0.43535\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.21287\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.586\ \mathrm{kipft/ft})) + ((-0.43535\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.90067\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4912\ \mathrm{ft})}{2}$$

$$p_a = 0.33684\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.21287\ \mathrm{kip/ft^2}\right)}{\left(0.33684\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.63196$$	Status: **PASS** Ratio: **0.630**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$ $$p_s = 0.975\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.90067\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92376$$	Status: **PASS** Ratio: **0.920**
	Considering z-direction: $H_o = 0.017197\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.05\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.05\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.017197\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.05\ \mathrm{kipft/ft})) + (4 \times (0.017197\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$ $$a = 4.6575\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.05\ \mathrm{kipft/ft})) + (3 \times (0.017197\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.05\ \mathrm{kipft/ft})) + (2 \times (0.017197\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$ $$p = 0.013619\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.05\ \mathrm{kipft/ft})) + ((0.017197\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$ $$s = 0.030076\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6575\ \mathrm{ft})}{2}$$ $$p_a = 0.34931\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.013619\ \mathrm{kip/ft^2}\right)}{\left(0.34931\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.038988$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

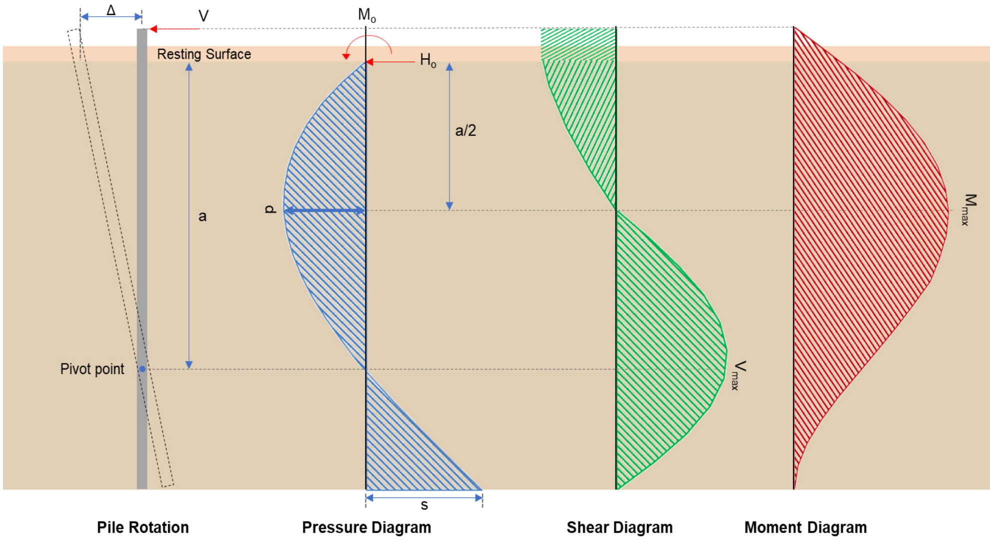
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.030076 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.030847$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.556 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.72548 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.383 \text{ kipft}) + ((-4.556 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.7043 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.7043 \text{ kipft/ft})}{(-0.72548 \text{ kip/ft})}$$

$$E = 10.62 \text{ ft}$$

a - Distance from resisting surface to pivot point,

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

$$a = \frac{(4 \times (7.7043 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.72548 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (7.7043\ \text{kipft/ft})) + (4 \times (-0.72548\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4903\ \text{ft}$$

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

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

$$V_{max} = ((-0.72548\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4903\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4903\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.303\ \text{kip}$$

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

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

$$M_{max} = ((-0.72548\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(10.62\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.774\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.175\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.027866\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.509\ \text{kipft}) + ((0.175\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.081051\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.081051\ \text{kipft/ft})}{(0.027866\ \text{kip/ft})}$$

$$E = 2.9086\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.081051\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (0.027866\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.081051\ \text{kipft/ft})) + (4 \times (0.027866\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6574\ \text{ft}$$

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

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

$$V_{max} = ((0.027866 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9086 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6574 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.9086 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6574 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.16265 \text{ kip}$$

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

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

$$M_{max} = ((0.027866 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(2.9086 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6574 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.9086 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6574 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9086 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6574 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.46409 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.402 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.35 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.35 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.402\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0027669$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 7.402\ \text{kip} \rightarrow 7402\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(7402\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.47\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.47\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.47\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.47\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.74\ \text{kip}$$

Considering x-direction:

$V_{max} = 10.303\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.303 \text{ kip})}{(110.74 \text{ kip})}$$ $$Ratio = 0.09304$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.16265 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.16265 \text{ kip})}{(110.74 \text{ kip})}$$ $$Ratio = 0.0014688$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 31.774 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.774 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.1273$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.46409 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.46409 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0018593$$		Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

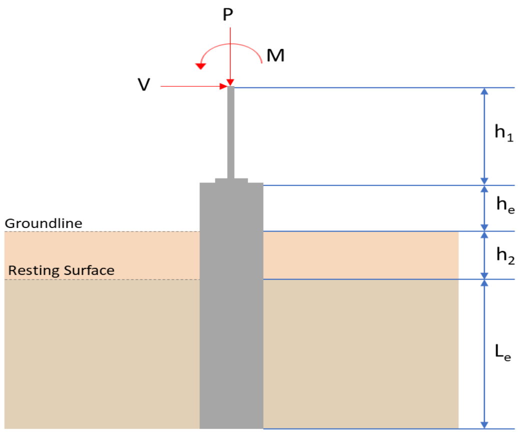
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.5$ 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)	4.797	7.401
V_x (kip)	-2.734	-4.555
V_z (kip)	-0.109	-0.176
M_x (kipft)	-0.319	-0.517
M_z (kipft)	28.793	48.372

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,

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

$$H_o = \frac{(-2.734\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.43535\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.793\text{ kipft}) + ((-2.734\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 4.5849\text{ kipft/ft}$$

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:
$L_{e,x} = 5.9555\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.109\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.017357\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.319\text{ kipft}) + ((-0.109\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.050796\text{ kipft/ft}$$

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:
$L_{e,z} = 1.3798\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.9555\text{ ft}), (1.3798\text{ ft})]$$

$$L_{e,req} = 5.955\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.955\text{ ft})}{(6.5\text{ ft})}$$

$$Ratio = 0.91615$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.797\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.29981\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.29981\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.14991$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.43535\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5849\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5849\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.43535\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.5849\ \text{kipft/ft})) + (4 \times (-0.43535\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4912\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.5849\ \text{kipft/ft})) + (3 \times (-0.43535\ \text{kip/ft}) \times (6.5\ \text{ft}))]^2}{(6.5\ \text{ft})^2 \times [(3 \times (4.5849\ \text{kipft/ft})) + (2 \times (-0.43535\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.21277\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.5849\ \text{kipft/ft})) + ((-0.43535\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.90035\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.4912\ \text{ft})}{2}$$

$$p_a = 0.33684\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21277\ \mathrm{kip/ft^2}\right)}{\left(0.33684\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.63165$$

Status: **PASS**
Ratio: **0.630**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.90035\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92344$$

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

Considering z-direction:

$H_o = -0.017357\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.050796\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.050796\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.017357\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.050796\ \mathrm{kipft/ft})) + (4 \times (-0.017357\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6566\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.050796\ \mathrm{kipft/ft})) + (3 \times (-0.017357\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.050796\ \mathrm{kipft/ft})) + (2 \times (-0.017357\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = -0.0044345\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.050796\ \mathrm{kipft/ft})) + ((-0.017357\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = -0.0015942\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6566\ \mathrm{ft})}{2}$$

$$p_a = 0.34925\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0044345\ \mathrm{kip/ft^2}\right)}{\left(0.34925\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.012697$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

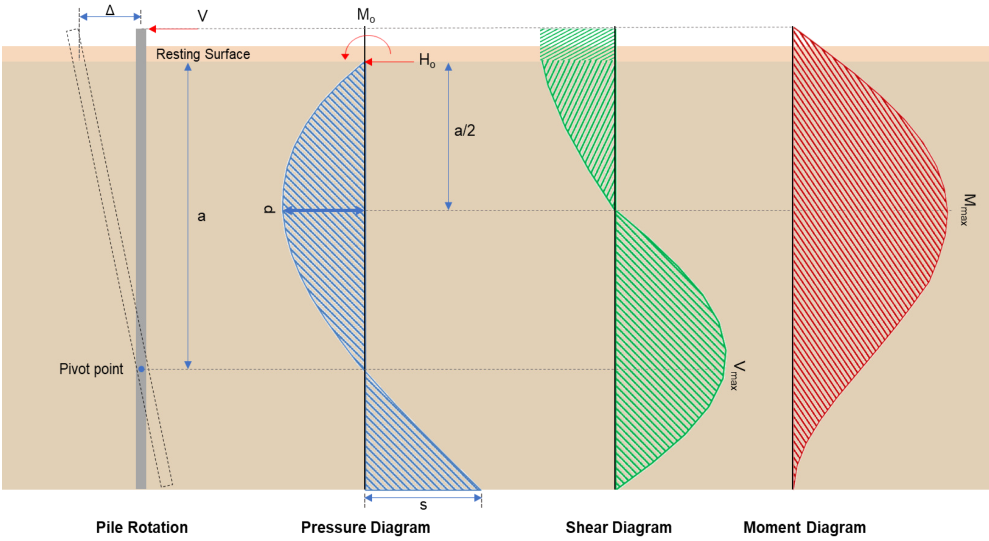
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0015942\ \mathrm{kip/ft^2})}{(0.975\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.0016351$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.555\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.72532\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.372\ \mathrm{kipft}) + ((-4.555\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.7025\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.7025\ \mathrm{kipft/ft})}{(-0.72532\ \mathrm{kip/ft})}$$

$$E = 10.62\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$\left(4 \times (7.7025\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})\right) + \left(3 \times (-0.72532\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (7.7025\ \text{kipft/ft})) + (4 \times (-0.72532\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4903\ \text{ft}$$

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

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

$$V_{max} = ((-0.72532\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4903\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4903\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.301\ \text{kip}$$

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

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

$$M_{max} = ((-0.72532\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(10.62\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.62\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4903\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.766\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.176\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.028025\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.517\ \text{kipft}) + ((-0.176\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.082325\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.082325\ \text{kipft/ft})}{(-0.028025\ \text{kip/ft})}$$

$$E = 2.9375\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.082325\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.028025\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.082325\ \text{kipft/ft})) + (4 \times (-0.028025\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6562\ \text{ft}$$

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

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

$$V_{max} = ((-0.028025\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9375\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6562\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.9375\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6562\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.16445\ \text{kip}$$

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

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

$$M_{max} = ((-0.028025\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(2.9375\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.6562\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.9375\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6562\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9375\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6562\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.46956\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.401\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.35\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.35\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.401\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0027665$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.401 \text{ kip} \rightarrow 7401 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7401 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.47 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.47 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.47 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.47 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.74 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.301 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.301 \text{ kip})}{(110.74 \text{ kip})}$$

$$Ratio = 0.093019$$

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

Considering z-direction:

$V_{max} = 0.16445 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.16445 \text{ kip})}{(110.74 \text{ kip})}$$

$$Ratio = 0.0014851$$

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:

$M_{max} = 31.766 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(31.766 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.12727$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$M_{max} = 0.46956 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.46956 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0018813$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

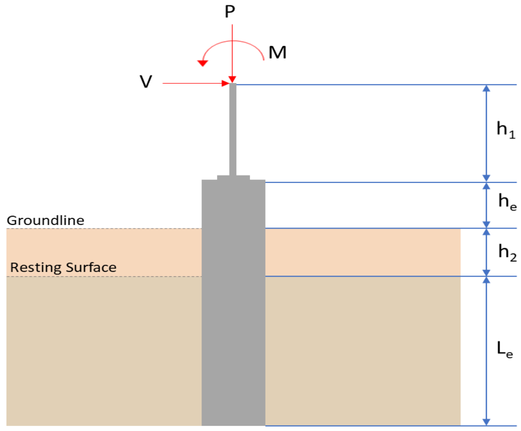
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.75$ 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)	5.422	8.393
V_x (kip)	-3.097	-5.158
V_z (kip)	-0.013	-0.022
M_x (kipft)	-0.037	-0.062
M_z (kipft)	32.520	54.662

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,

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

$$H_o = \frac{(-3.097\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.49315\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.52\ \text{kipft}) + ((-3.097\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.1783\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.1478\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.013\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0020701\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.037\ \text{kipft}) + ((-0.013\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0058917\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.72505\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.1478\ \text{ft}), (0.72505\ \text{ft})]$$

$$L_{e,req} = 6.148\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.148\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.91081$$

Status: **PASS**
Ratio: **0.910**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.422\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.33888\ \text{kip}/\text{ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33888\ \text{kip}/\text{ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.16944$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.49315\ \text{kip}/\text{ft}$ - Lateral force per length of pile,
$M_o = 5.1783\ \text{kipft}/\text{ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1783\ \text{kipft}/\text{ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.49315\ \text{kip}/\text{ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (5.1783\ \text{kipft}/\text{ft})) + (4 \times (-0.49315\ \text{kip}/\text{ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6687\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1783\ \text{kipft}/\text{ft})) + (3 \times (-0.49315\ \text{kip}/\text{ft}) \times (6.75\ \text{ft})]^2}{(6.75\ \text{ft})^2 \times [(3 \times (5.1783\ \text{kipft}/\text{ft})) + (2 \times (-0.49315\ \text{kip}/\text{ft}) \times (6.75\ \text{ft}))]}$$

$$p = 0.21337\ \text{kip}/\text{ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1783\ \text{kipft}/\text{ft})) + ((-0.49315\ \text{kip}/\text{ft}) \times (6.75\ \text{ft}))]}{(6.75\ \text{ft})^2}$$

$$s = 0.92549\ \text{kip}/\text{ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf}/\text{ft}) \times \frac{(4.6687\ \text{ft})}{2}$$

$$p_a = 0.35016\ \text{kip}/\text{ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21337\ \text{kip/ft}^2\right)}{\left(0.35016\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.60934$$

Status: **PASS**
Ratio: **0.610**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.75\ \text{ft})$$

$$p_s = 1.0125\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.92549\ \text{kip/ft}^2\right)}{\left(1.0125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.91406$$

Status: **PASS**
Ratio: **0.910**

Considering z-direction:

$H_o = -0.0020701\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0058917\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058917\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.0020701\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (0.0058917\ \text{kipft/ft})) + (4 \times (-0.0020701\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.8446\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0058917\ \text{kipft/ft})) + (3 \times (-0.0020701\ \text{kip/ft}) \times (6.75\ \text{ft}))]^{\ 2}}{(6.75\ \text{ft})^2 \times [(3 \times (0.0058917\ \text{kipft/ft})) + (2 \times (-0.0020701\ \text{kip/ft}) \times (6.75\ \text{ft}))]}$$

$$p = -0.00053978\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0058917\ \text{kipft/ft})) + ((-0.0020701\ \text{kip/ft}) \times (6.75\ \text{ft}))]}{(6.75\ \text{ft})^2}$$

$$s = -0.00028833\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.8446\ \text{ft})}{2}$$

$$p_a = 0.36334\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00053978\ \text{kip/ft}^2\right)}{\left(0.36334\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.0014856$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

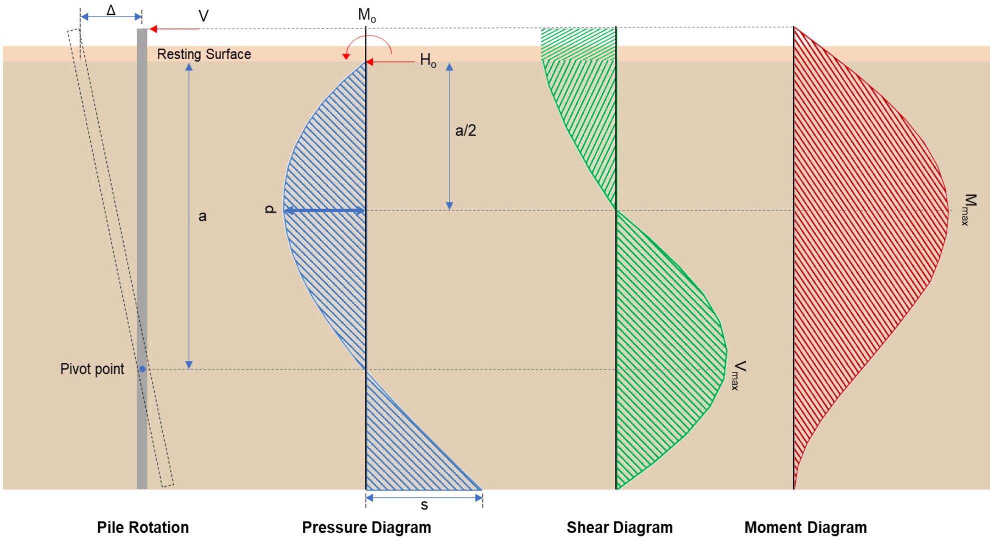
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00028833\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00028477$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.158\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.82134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.662\ \mathrm{kipft}) + ((-5.158\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.7041\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.7041\ \mathrm{kipft/ft})}{(-0.82134\ \mathrm{kip/ft})}$$

$$E = 10.598\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7041\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.82134\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (8.7041 \text{ kipft/ft})) + (4 \times (-0.82134 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6677 \text{ ft}$$

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

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

$$V_{max} = ((-0.82134 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.598 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.6677 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.598 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.6677 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 11.293 \text{ kip}$$

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

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

$$M_{max} = ((-0.82134 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(10.598 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6677 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (10.598 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.6677 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.598 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.6677 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 36.104 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.022 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0035032 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.062 \text{ kipft}) + ((-0.022 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0098726 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0098726 \text{ kipft/ft})}{(-0.0035032 \text{ kip/ft})}$$

$$E = 2.8182 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0098726 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.0035032 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.0098726 \text{ kipft/ft})) + (4 \times (-0.0035032 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8459 \text{ ft}$$

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

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

	$$V_{max} = ((-0.0035032\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8182\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8459\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8182\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8459\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$ $$V_{max} = 0.019715\ \text{kip}$$ M_{max} - Max bending moment located at depth a/2, $$M_{max} = (H_o\, b\, L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2\,L_e}\right) - \left[\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{2\,L_e}\right)^3\right] + \left[\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{2\,L_e}\right)^4\right]\right]$$ $$M_{max} = ((-0.0035032\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(2.8182\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.8459\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.8182\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8459\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8182\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8459\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$ $$M_{max} = 0.05812\ \text{kipft}$$	
Table 22.4.2.1 *22.4.2.2, 10.6.1.1*	**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, $\alpha = 0.8$ - Alpha factor for axial strength, $A_g = 2304\ \text{in}^2$ - Gross area of concrete, **Longitudinal reinforcement:** Required reinforcement due to axial load, $A_{st,required}$ $A_{st,required}$ $$A_{st,required} = Min\left[\frac{\frac{P}{\phi\,\alpha} - (0.85\, f'_{ck}\, A_g)}{f_{yk} - (0.85\, f'_{ck})}, (0.08\, A_g)\right]$$ $$A_{st,required} = Min\left[\frac{\frac{(8.393\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$ $$A_{st,required} = -84.317\ \text{in}^2$$ A_{min} - Governing minimum reinforcement area, $$A_{min} = Max[A_{st,required}, (0.0018\, A_g)]$$ $$A_{min} = Max\left[(-84.317\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$ $$A_{min} = 4.1472\ \text{in}^2$$ n_{rebar} - Required number of reinforcement, $$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$ $$n_{rebar} = \frac{(4.1472\ \text{in}^2)}{(0.3068\ \text{in}^2)}$$ $$n_{rebar} = 14$$ A_{st} - Actual total reinforcement area, $$A_{st} = n_{rebar}\,\frac{\pi\, d_{bar}^2}{4}$$ $$A_{st} = (14) \times \frac{\pi \times (0.625\ \text{in})^2}{4}$$ $$A_{st} = 4.2951\ \text{in}^2$$ $Ratio$ - Capacity $$Ratio = \frac{A_{min}}{A_{st}}$$ $$Ratio = \frac{(4.1472\ \text{in}^2)}{(4.2951\ \text{in}^2)}$$	

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.393\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0031374$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}, P = 8.393 \text{ kip} \rightarrow 8393 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8393 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.6 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.6 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.82 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.293 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(11.293\text{ kip})}{(110.82\text{ kip})}$$ $$Ratio = 0.1019$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.019715\text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.019715\text{ kip})}{(110.82\text{ kip})}$$ $$Ratio = 0.00017789$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\text{ in}) \times (48\text{ in})^2}{6}$$ $$S_m = 18432\text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\,0.85\,f'_{ck}\,S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 36.104\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(36.104\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.14465$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $M_{max} = 0.05812\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

		$$Ratio = \frac{(0.05812 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00023285$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

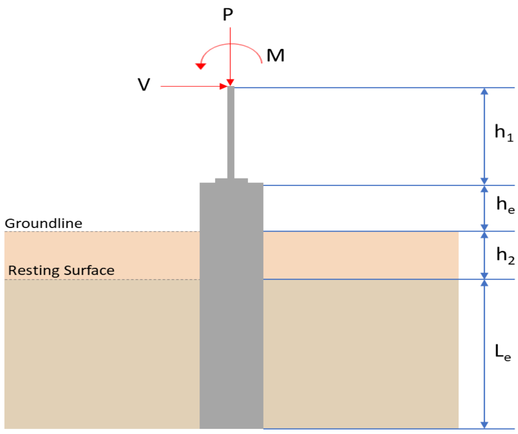
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.75$ 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)	5.424	8.396
V_x (kip)	-3.098	-5.161
V_z (kip)	0.013	0.023
M_x (kipft)	0.038	0.064
M_z (kipft)	32.537	54.690

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,

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

$$H_o = \frac{(-3.098 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49331 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.537 \text{ kipft}) + ((-3.098 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.1811 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.1489 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.013 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0020701 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038 \text{ kipft}) + ((0.013 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.006051 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.8378 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.1489 \text{ ft}), (0.8378 \text{ ft})]$$

$$L_{e,req} = 6.149 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.149 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.91096$$

Status: **PASS**
Ratio: **0.910**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.424 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.339 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.339 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.1695$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.49331 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.1811 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1811 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.49331 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (5.1811 \text{ kipft/ft})) + (4 \times (-0.49331 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6687 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1811 \text{ kipft/ft})) + (3 \times (-0.49331 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\ 2}}{(6.75 \text{ ft})^2 \times [(3 \times (5.1811 \text{ kipft/ft})) + (2 \times (-0.49331 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.21352 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1811 \text{ kipft/ft})) + ((-0.49331 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.92606 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6687 \text{ ft})}{2}$$

$$p_a = 0.35015 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.21352 \text{ kip/ft}^2\right)}{\left(0.35015 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.6098$$	Status: **PASS** Ratio: **0.610**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$ $$p_s = 1.0125 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.92606 \text{ kip/ft}^2\right)}{\left(1.0125 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.91462$$	Status: **PASS** Ratio: **0.910**

Considering z-direction:

$H_o = 0.0020701 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.006051 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.006051 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (0.0020701 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.006051 \text{ kipft/ft})) + (4 \times (0.0020701 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.841 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.006051 \text{ kipft/ft})) + (3 \times (0.0020701 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.006051 \text{ kipft/ft})) + (2 \times (0.0020701 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.0015612 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.006051 \text{ kipft/ft})) + ((0.0020701 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.0034337 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.841 \text{ ft})}{2}$$

$$p_a = 0.36307 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0015612 \text{ kip/ft}^2\right)}{\left(0.36307 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0043$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.75\ \text{ft})$$

$$p_s = 1.0125\ \text{kip/ft}^2$$

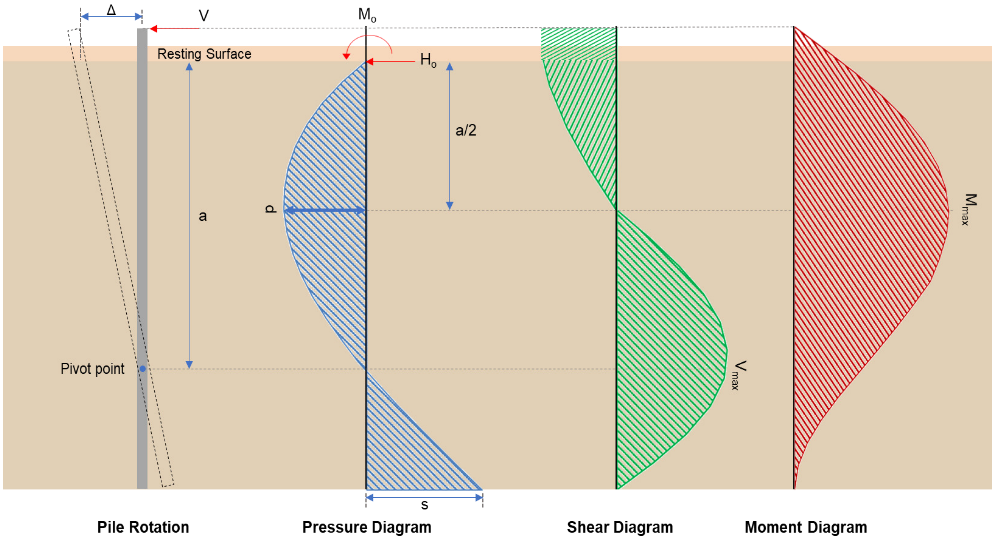
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0034337\ \text{kip/ft}^2)}{(1.0125\ \text{kip/ft}^2)}$$

$$Ratio = 0.0033913$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.161\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.82182\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.69\ \text{kipft}) + ((-5.161\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.7086\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.7086\ \text{kipft/ft})}{(-0.82182\ \text{kip/ft})}$$

$$E = 10.597\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7086\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.82182\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (8.7086\ \mathrm{kipft/ft})) + (4 \times (-0.82182\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6677\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.82182\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.597\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6677\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.597\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6677\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.299\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.82182\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(10.597\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6677\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (10.597\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6677\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.597\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6677\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 36.123\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.023\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0036624\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.064\ \mathrm{kipft}) + ((0.023\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.010191\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.010191\ \mathrm{kipft/ft})}{(0.0036624\ \mathrm{kip/ft})}$$

$$E = 2.7826\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010191\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.0036624\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.010191\ \mathrm{kipft/ft})) + (4 \times (0.0036624\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8476\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0036624\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.7826\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8476\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.7826\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8476\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.020476\ \text{kip}$$

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

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

$$M_{max} = ((0.0036624\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(2.7826\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.8476\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.7826\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8476\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.7826\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8476\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.060309\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(8.396\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.317\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.317\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[(16\, d_{bar}), (48\, d_{ties}), Min\,(D, b)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\text{ in})), (48 \times (0.375\text{ in})), Min\,((48\text{ in}), (48\text{ in}))\right]$$ $$s_{ties} = 10\text{ in}$$	
	Summary: Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(8.396\text{ kip})}{(2675.2\text{ kip})}$$ $$Ratio = 0.0031385$$	Status: **PASS** Ratio: **0.000**
22.5.2.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\text{ in})$$ $$d = 38.4\text{ in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$	
22.5.5.1.1	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.396 \text{ kip} \rightarrow 8396 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8396 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.6 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.6 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.82 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.299 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(11.299\ \text{kip})}{(110.82\ \text{kip})}$$ $$Ratio = 0.10196$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.020476\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.020476\ \text{kip})}{(110.82\ \text{kip})}$$ $$Ratio = 0.00018476$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 36.123\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(36.123\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.14472$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $M_{max} = 0.060309\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.060309 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00024162$$	Status: **PASS** Ratio: **0.000**