Project Details

Project Name: Bozeman Trail RV _ Fenceline - V1JB

Location: 31842 Frontage Rd, Bozeman, MT 59715, USA

Unique ID: 5P-19.75-8TOP-XD-24-L-5Hx13W-3EC0

Dealer: ______________________________

Date: Wed Apr 16 2025

Number of Modules: 65

Number of Poles: 5

Date Sold:

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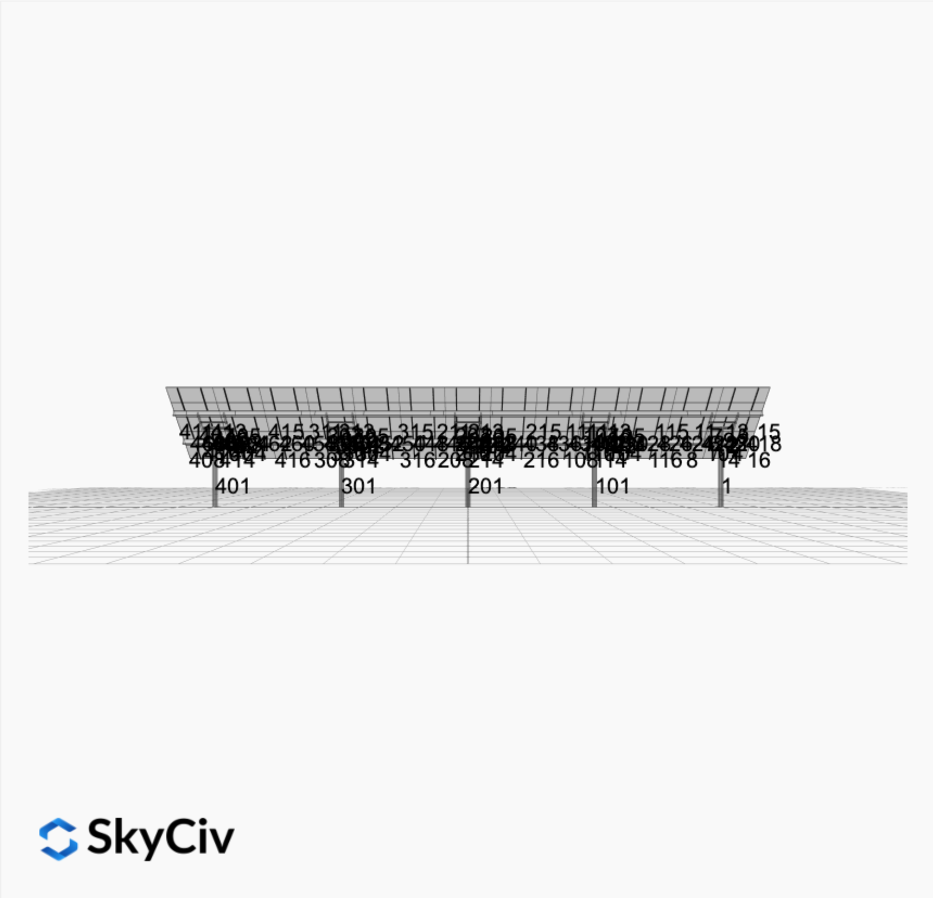


Array Dimensions N/S	18.79 ft
Array Dimensions E/W	90.57 ft
Winter Tilt Angle	35
Front Edge Clearance	7 ft

MT Solar Bill of Materials (5P-19.75-8TOP-XD-24-L-5Hx13W-3EC0)

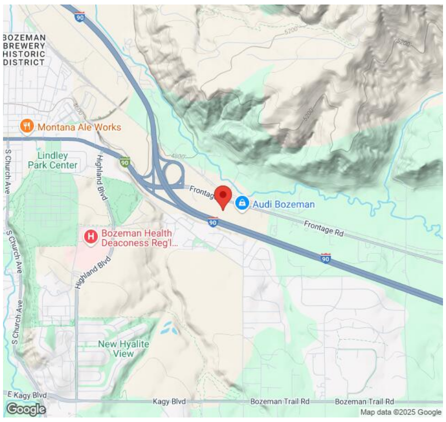
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	5
MTS-HF-XD	H-Frame Assembly-XD	5
MTS-XD-Wing-24	24IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	8
MTS-XD-Splice-57	57IN XD Splice	8
MTS-CLAMP-ANGLE-4PK	Angle Clamp	13

Rail Bill of Materials

Part	Qty
Rails (226in)	26
Rail Attachment	104

Part	Qty
Module Mid Clamp	104
Module End Clamp	52
Ground Lug	13

Site Details:



Site Address: 31842 Frontage Rd, Bozeman, MT 59715, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	82.60in
Number of Rows:	5
Number of Columns:	13
Total Number of Modules:	65
Winter Tilt Angle:	35
Front Edge Clearance:	7
Total Array Height at Tilt:	17.78 ft
Total Frame Length:	90.50 ft
Module Info/Notes:	
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	90.57 ft
Rail Length:	225.50 in
Rail Spacing:	3.48 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	12.39 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.75 ft Pile 2: 7.25 ft Pile 3: 7.50 ft Pile 4: 7.25 ft Pile 5: 6.75 ft
Foundation Volume:	21.037 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	31842 Frontage Rd, Bozeman, MT 59715, USA
Wind Speed:	115 mph

Snow Load:	51 psf

Design Disclaimer

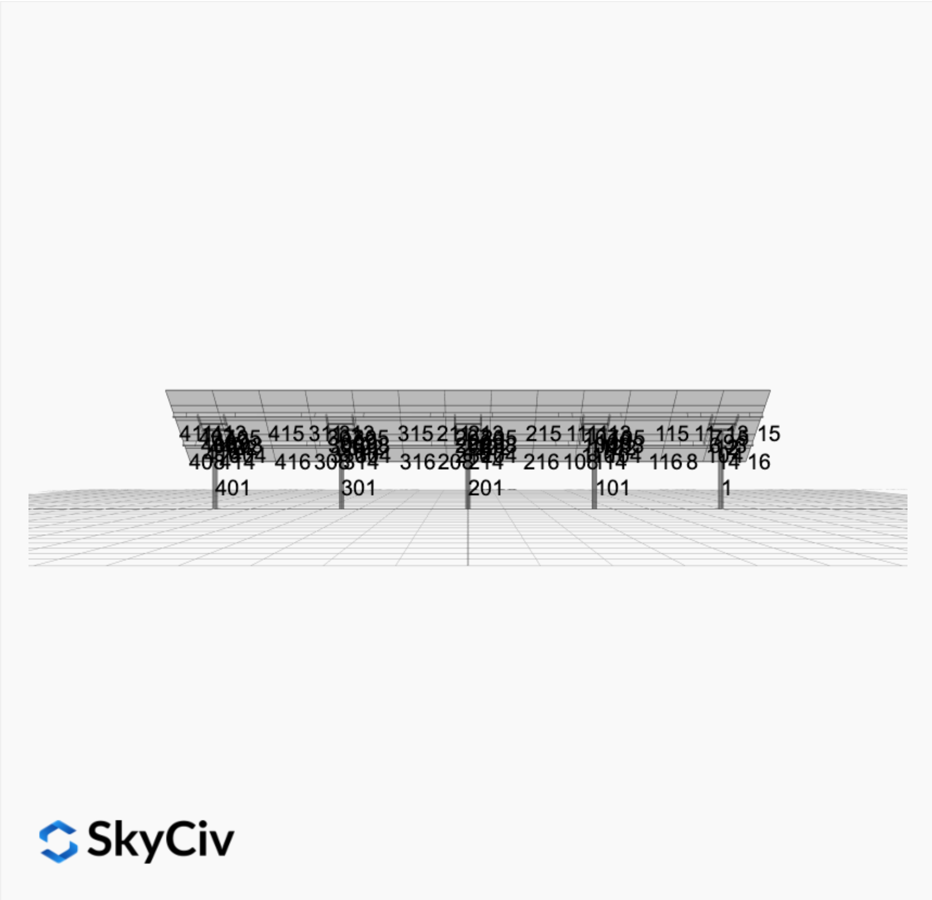
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input

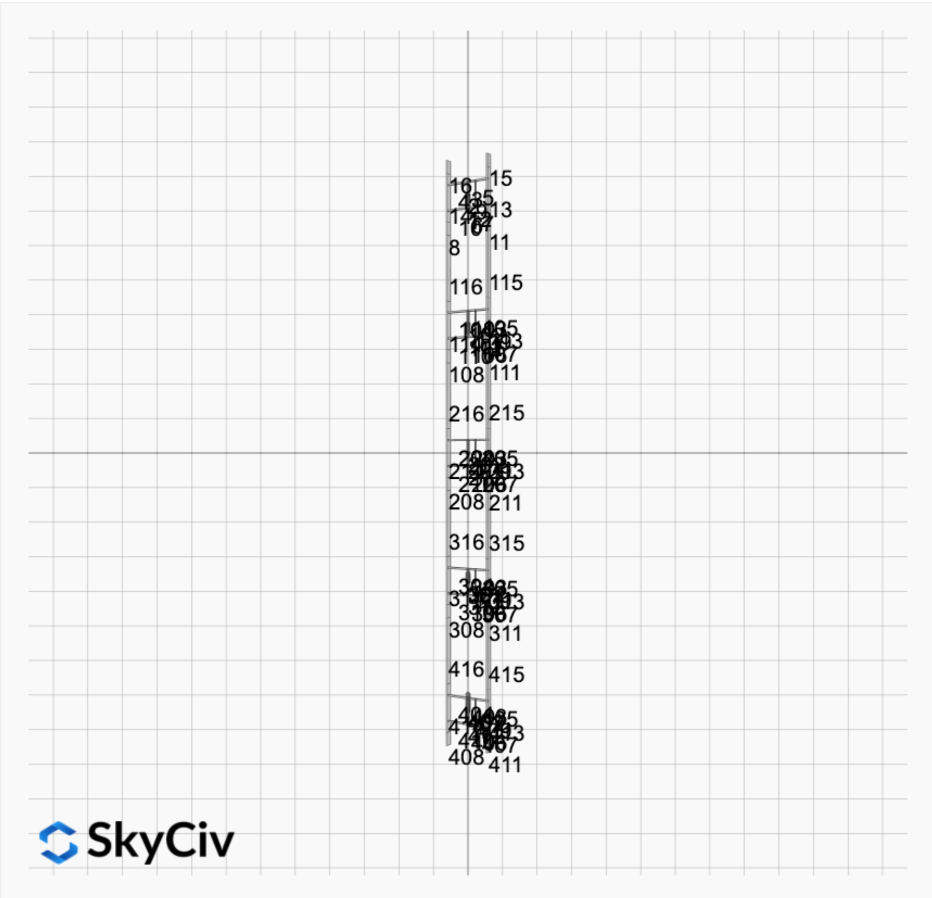
{"wind_speed_override":115,"snow_load_override":51,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Blake Bjornson","designer_email":"sales@onsiteenergyinc.com","designer_phone":"4064718730","project_id":"Bozeman Trail RV _ Fenceline - V1JB","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_info":"","module_width":44.6,"module_length":82.6,"number_rows":"5","number_columns":13,"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":35,"ground_clearance":7,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"auto","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)




401
-14.95
7.70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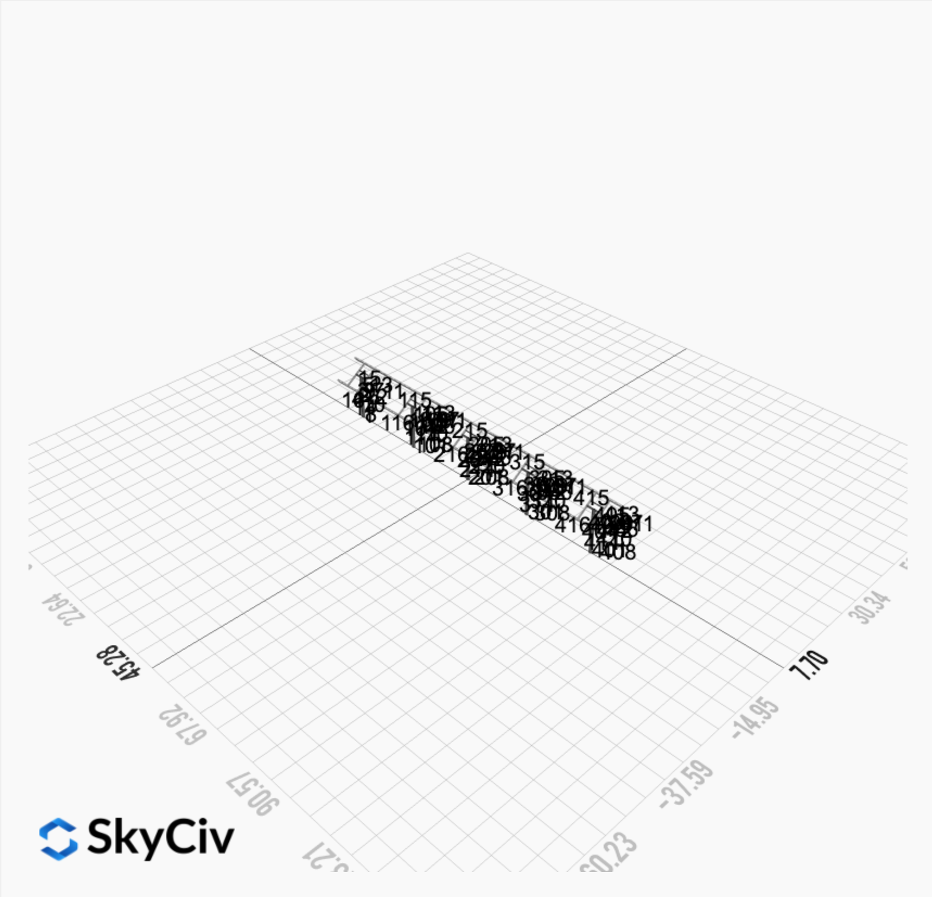
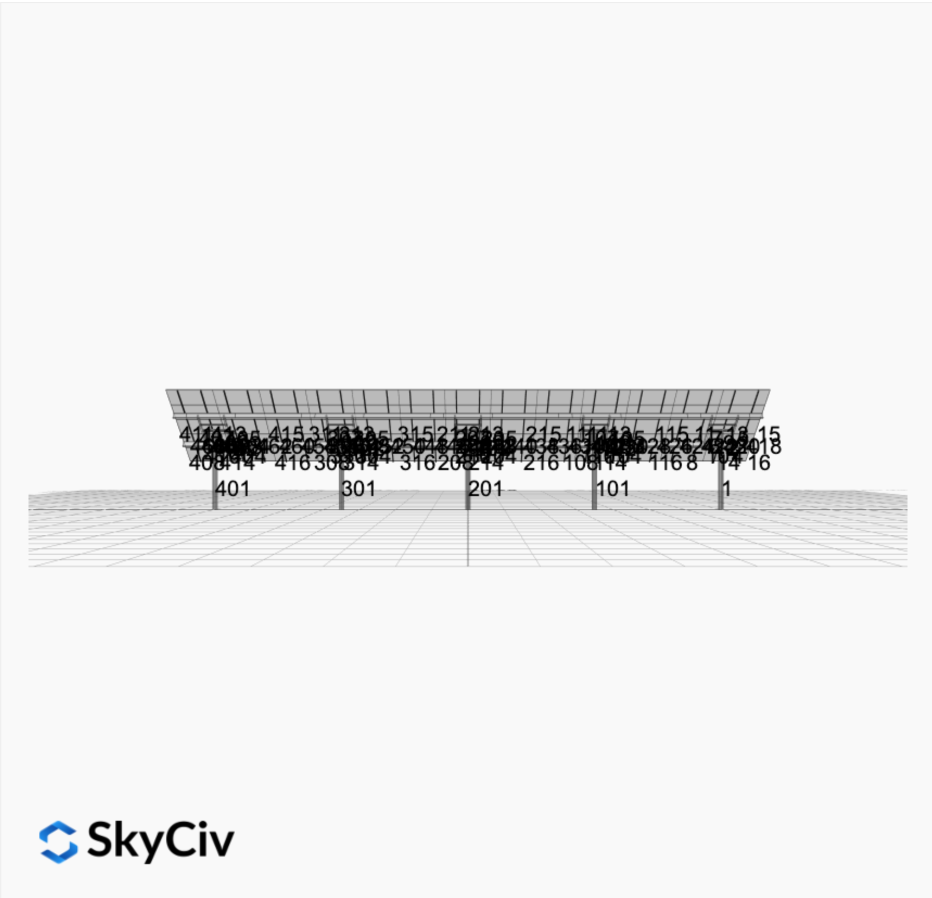
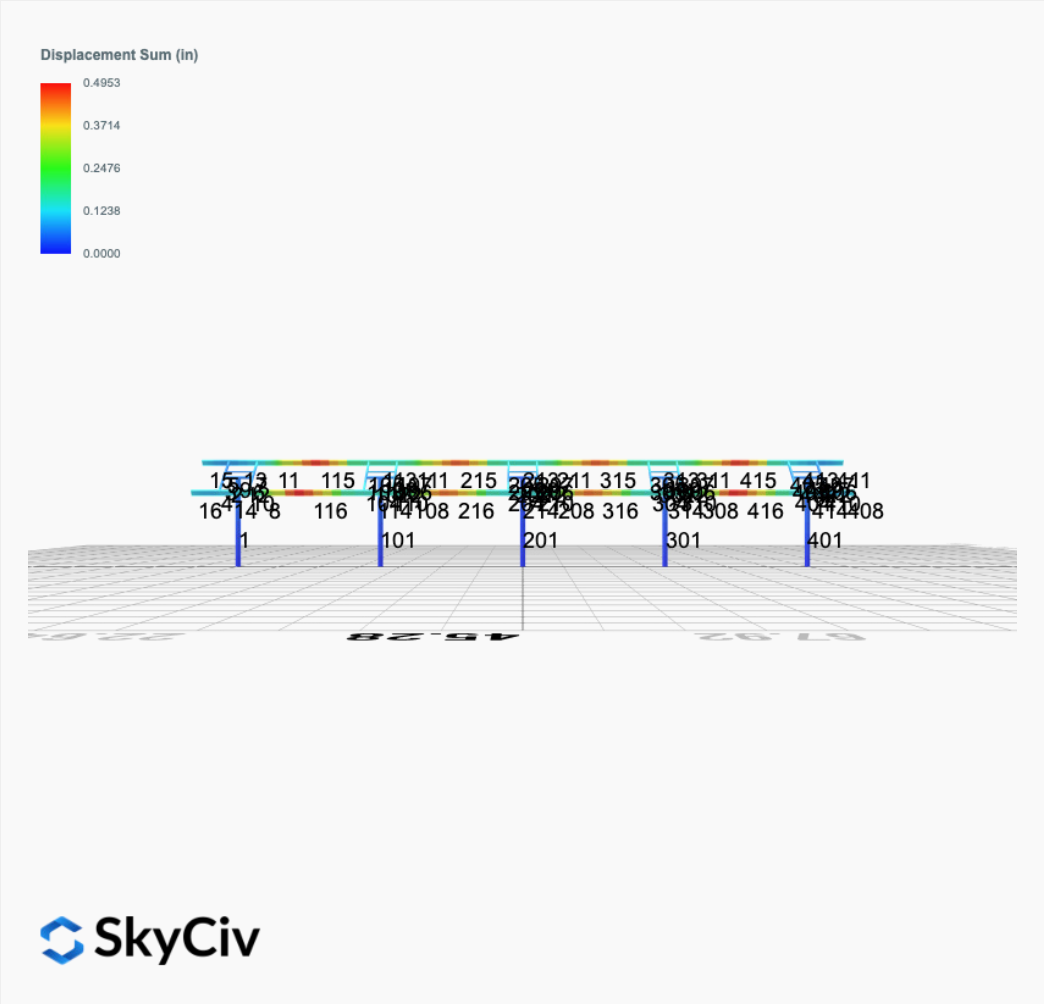
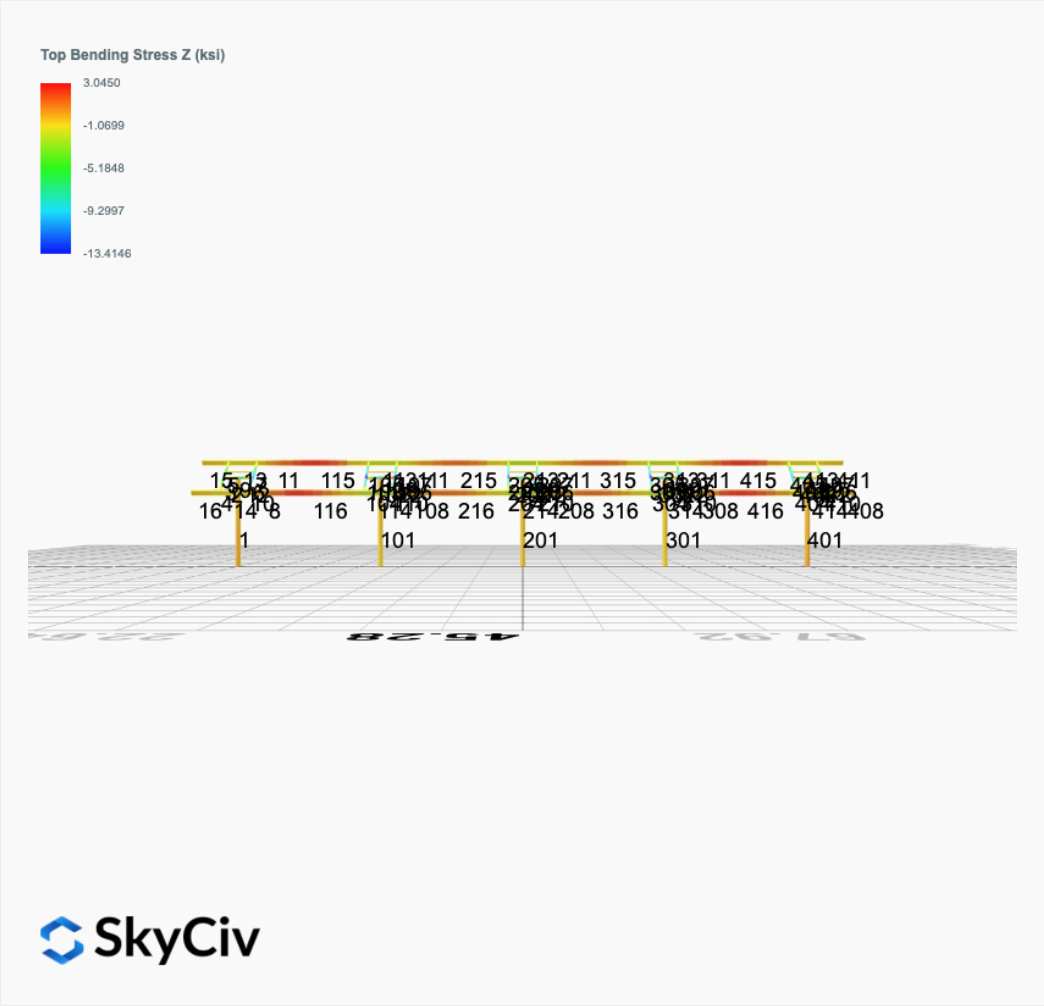




FEM Results (Envelope Worst Case for each member)





Top Bending Stress Z (ksi)
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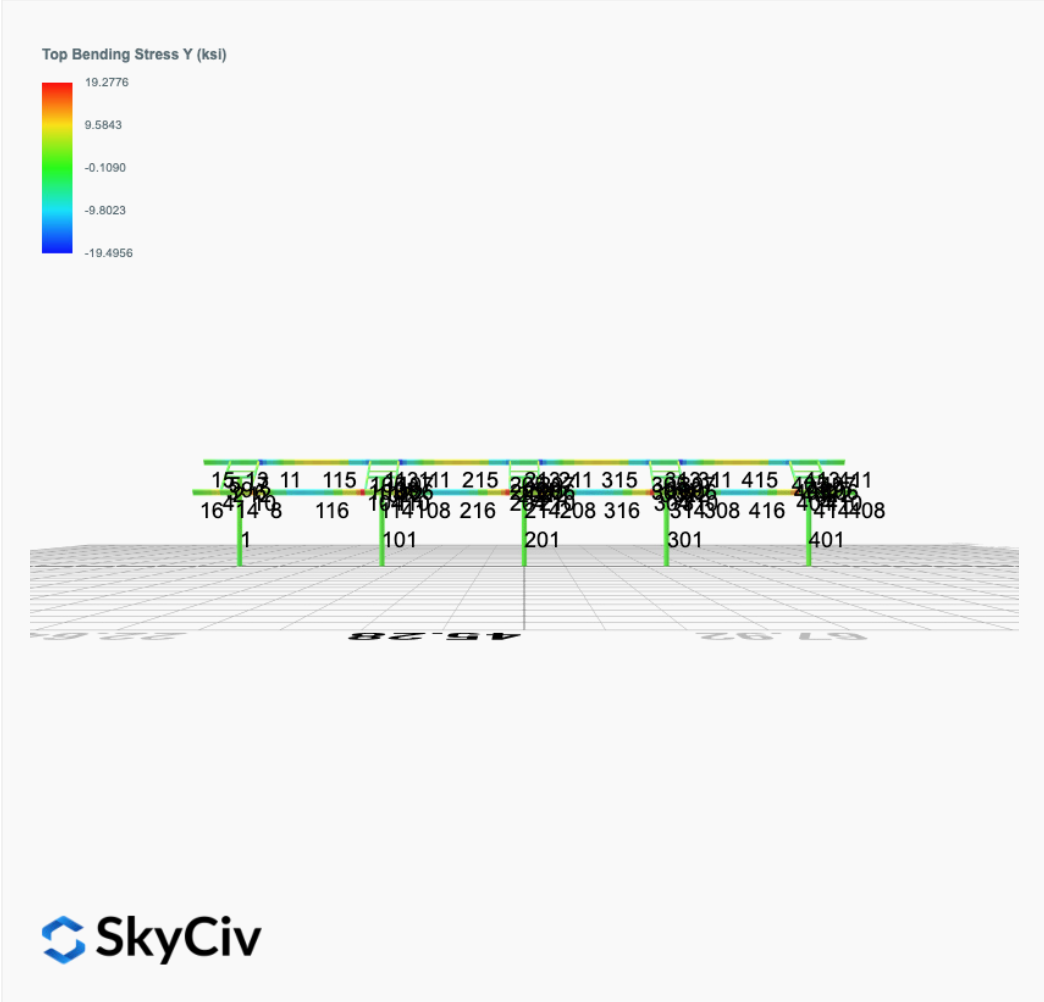
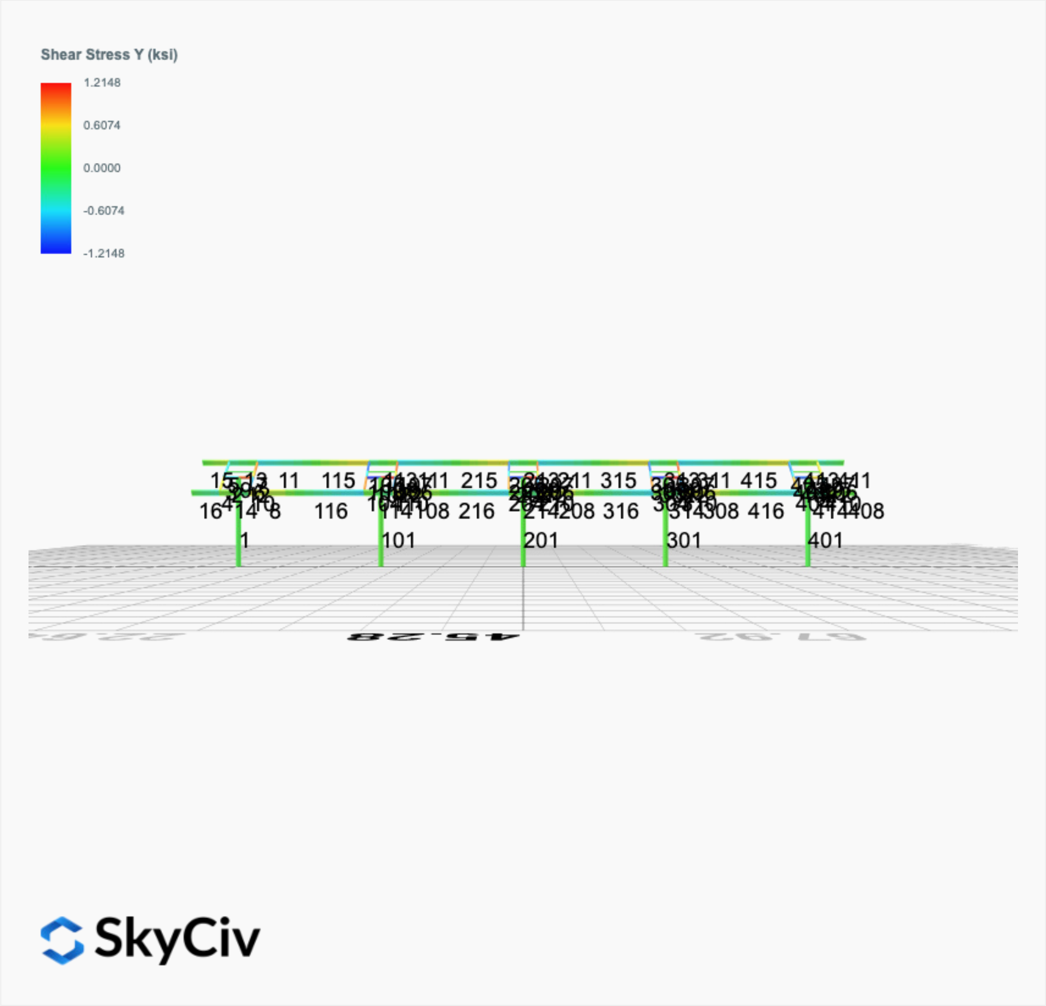
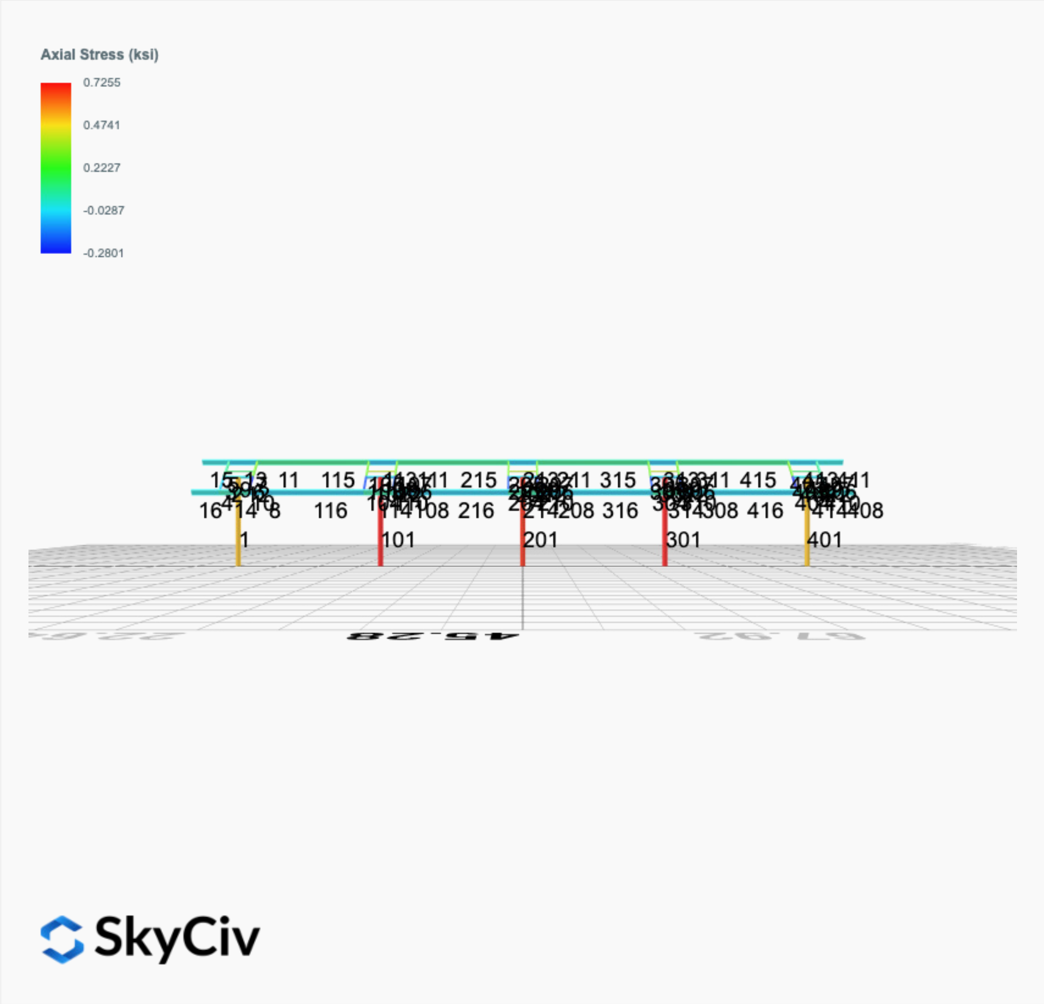
-1.0699
-5.1848
-9.2997
-13.4146
1
101
201
301
401
SkyCiv


Top Bending Stress Y (ksi)
19.2776
9.5843
-0.1090
-9.8023
-19.4956
SkyCiv



Shear Stress Y (ksi)
1.2148
0.6074
0.0000
-0.6074
-1.2148
1
101
201
301
401
SkyCiv


Axial Stress (ksi)
0.7255
0.4741
0.2227
-0.0287
-0.2801
101
201
301
401
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	0.0279	2.2643	0.0694	0.2647	-0.0504	-0.2921
ULS: 2. D + L	0.0279	2.2643	0.0694	0.2647	-0.0504	-0.2921
ULS: 3. D + (S or Lr or R)	0.1058	6.8538	0.2647	1.0118	-0.1937	-1.1749
ULS: 3. D + (S or Lr or R)	0.0279	2.2643	0.0694	0.2647	-0.0504	-0.2921
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0864	5.7064	0.2158	0.8250	-0.1579	-0.9542
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0279	2.2643	0.0694	0.2647	-0.0504	-0.2921
ULS: 5b. D + 0.7E	0.0279	2.2643	0.0694	0.2647	-0.0504	-0.2921
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0864	5.7064	0.2158	0.8250	-0.1579	-0.9542
ULS: 8. 0.6D + 0.7E	0.0167	1.3586	0.0416	0.1588	-0.0303	-0.1753
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5066	5.7921	0.3142	1.1680	-0.7645	32.3782
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.5066	5.7921	0.3142	1.1680	-0.7645	32.3782
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1589	-0.7073	-0.1291	-0.4656	0.5278	-26.4909
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8333	-0.2285	-0.1223	-0.4401	0.5168	-29.6122
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8145	8.3523	0.3995	1.5025	-0.6934	23.5486
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8145	8.3523	0.3995	1.5025	-0.6934	23.5486
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6846	3.4777	0.0670	0.2774	0.2758	-20.6033
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4404	3.8368	0.0721	0.2964	0.2676	-22.9443
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8730	4.9101	0.2530	0.9421	-0.5860	24.2107
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8730	4.9101	0.2530	0.9421	-0.5860	24.2107
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6261	0.0356	-0.0795	-0.2830	0.3832	-19.9412
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3820	0.3947	-0.0744	-0.2639	0.3750	-22.2822
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5178	4.8864	0.2864	1.0621	-0.7443	32.4951
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.5178	4.8864	0.2864	1.0621	-0.7443	32.4951
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1477	-1.6130	-0.1569	-0.5714	0.5480	-26.3741
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8222	-1.1343	-0.1501	-0.5460	0.5370	-29.4954

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.0035
Shear X	-4.2242
Shear Z	0.6070
Moment X	2.2999
Moment Y (Twist)	1.3415
Moment Z	54.8131

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.3523
Shear X	-2.5178
Shear Z	0.3995
Moment X	1.5025
Moment Y (Twist)	0.7645
Moment Z	32.4951

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	-0.0255	2.8015	-0.0040	-0.0162	0.0111	0.3037
ULS: 2. D + L	-0.0255	2.8015	-0.0040	-0.0162	0.0111	0.3037
ULS: 3. D + (S or Lr or R)	-0.0969	8.8951	-0.0152	-0.0613	0.0418	1.1141
ULS: 3. D + (S or Lr or R)	-0.0255	2.8015	-0.0040	-0.0162	0.0111	0.3037
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0790	7.3717	-0.0124	-0.0500	0.0341	0.9115

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0255	2.8015	-0.0040	-0.0162	0.0111	0.3037
ULS: 5b. D + 0.7E	-0.0255	2.8015	-0.0040	-0.0162	0.0111	0.3037
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0790	7.3717	-0.0124	-0.0500	0.0341	0.9115
ULS: 8. 0.6D + 0.7E	-0.0153	1.6809	-0.0024	-0.0097	0.0067	0.1822
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.2475	7.4837	0.0270	0.0932	-0.1279	41.3019
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.2475	7.4837	0.0270	0.0932	-0.1279	41.3019
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7005	-1.1558	-0.0250	-0.0892	0.1103	-32.4271
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2160	-0.4726	-0.0380	-0.1370	0.1541	-35.6672
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4955	10.8833	0.0109	0.0321	-0.0701	31.6602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4955	10.8833	0.0109	0.0321	-0.0701	31.6602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9655	4.4037	-0.0281	-0.1047	0.1086	-23.6366
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6021	4.9161	-0.0379	-0.1406	0.1414	-26.0666
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4420	6.3131	0.0193	0.0659	-0.0931	31.0523
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4420	6.3131	0.0193	0.0659	-0.0931	31.0523
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0190	-0.1665	-0.0198	-0.0709	0.0855	-24.2444
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6556	0.3459	-0.0295	-0.1068	0.1184	-26.6745
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.2372	6.3631	0.0287	0.0997	-0.1323	41.1804
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.2372	6.3631	0.0287	0.0997	-0.1323	41.1804
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7107	-2.2764	-0.0234	-0.0827	0.1059	-32.5486
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2262	-1.5932	-0.0364	-0.1305	0.1497	-35.7886

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	17.0075
Shear X	-5.4292
Shear Z	-0.0710
Moment X	-0.2576
Moment Y (Twist)	0.2809
Moment Z	70.7302

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.8833
Shear X	-3.2475
Shear Z	-0.0380
Moment X	-0.1406
Moment Y (Twist)	0.1541
Moment Z	41.3019

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	-0.0047	2.7601	0.0000	-0.0000	0.0000	0.1229
ULS: 2. D + L	-0.0047	2.7601	0.0000	-0.0000	0.0000	0.1229
ULS: 3. D + (S or Lr or R)	-0.0179	8.7381	0.0000	-0.0001	0.0001	0.4287
ULS: 3. D + (S or Lr or R)	-0.0047	2.7601	0.0000	-0.0000	0.0000	0.1229
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0146	7.2436	0.0000	-0.0001	0.0001	0.3522
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0047	2.7601	0.0000	-0.0000	0.0000	0.1229
ULS: 5b. D + 0.7E	-0.0047	2.7601	0.0000	-0.0000	0.0000	0.1229
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0146	7.2436	0.0000	-0.0001	0.0001	0.3522
ULS: 8. 0.6D + 0.7E	-0.0028	1.6560	0.0000	-0.0000	0.0000	0.0737
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.2483	7.4145	0.0000	-0.0000	0.0000	41.8800
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.2483	7.4145	0.0000	-0.0000	0.0000	41.8800
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7321	-1.1637	0.0000	-0.0000	0.0000	-33.1042
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2770	-0.5241	0.0000	-0.0000	0.0000	-36.7564

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	-2.4474	10.7344	0.0000	-0.0001	0.0001	31.6700
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4474	10.7344	0.0000	-0.0001	0.0001	31.6700
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0379	4.3008	0.0000	-0.0001	0.0001	-24.5681
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6966	4.7805	0.0000	-0.0001	0.0001	-27.3072
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4374	6.2509	0.0000	-0.0000	0.0000	31.4407
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4374	6.2509	0.0000	-0.0000	0.0000	31.4407
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0479	-0.1828	0.0000	-0.0000	0.0000	-24.7974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.7066	0.2970	0.0000	-0.0000	0.0000	-27.5366
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.2465	6.3105	0.0000	-0.0000	0.0000	41.8308
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.2465	6.3105	0.0000	-0.0000	0.0000	41.8308
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7340	-2.2677	0.0000	-0.0000	0.0000	-33.1533
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2789	-1.6281	0.0000	-0.0000	0.0000	-36.8056

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	16.7608
Shear X	-5.4192
Shear Z	0.0000
Moment X	-0.0005
Moment Y (Twist)	0.0008
Moment Z	71.6539

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.7344
Shear X	-3.2483
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0001
Moment Z	41.8800

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	-0.0255	2.8015	0.0040	0.0162	-0.0111	0.3037
ULS: 2. D + L	-0.0255	2.8015	0.0040	0.0162	-0.0111	0.3037
ULS: 3. D + (S or Lr or R)	-0.0969	8.8951	0.0152	0.0612	-0.0416	1.1141
ULS: 3. D + (S or Lr or R)	-0.0255	2.8015	0.0040	0.0162	-0.0111	0.3037
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0790	7.3717	0.0124	0.0499	-0.0340	0.9115
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0255	2.8015	0.0040	0.0162	-0.0111	0.3037
ULS: 5b. D + 0.7E	-0.0255	2.8015	0.0040	0.0162	-0.0111	0.3037
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0790	7.3717	0.0124	0.0499	-0.0340	0.9115
ULS: 8. 0.6D + 0.7E	-0.0153	1.6809	0.0024	0.0097	-0.0067	0.1822
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.2475	7.4837	-0.0270	-0.0932	0.1279	41.3019
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.2475	7.4837	-0.0270	-0.0932	0.1279	41.3019
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7005	-1.1558	0.0250	0.0892	-0.1103	-32.4271
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2160	-0.4726	0.0380	0.1370	-0.1541	-35.6672
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4955	10.8833	-0.0109	-0.0322	0.0703	31.6602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4955	10.8833	-0.0109	-0.0322	0.0703	31.6602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9655	4.4037	0.0281	0.1046	-0.1084	-23.6366
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6021	4.9161	0.0379	0.1405	-0.1412	-26.0666
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4420	6.3131	-0.0193	-0.0659	0.0932	31.0523
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4420	6.3131	-0.0193	-0.0659	0.0932	31.0523
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0190	-0.1665	0.0198	0.0709	-0.0855	-24.2444
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6556	0.3459	0.0295	0.1068	-0.1183	-26.6745

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.2372	6.3631	-0.0287	-0.0997	0.1324	41.1804
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.2372	6.3631	-0.0287	-0.0997	0.1324	41.1804
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7107	-2.2764	0.0234	0.0827	-0.1059	-32.5486
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2262	-1.5932	0.0364	0.1305	-0.1496	-35.7886

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	17.0075
Shear X	-5.4292
Shear Z	0.0710
Moment X	0.2582
Moment Y (Twist)	0.2807
Moment Z	70.7305

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.8833
Shear X	-3.2475
Shear Z	0.0380
Moment X	0.1405
Moment Y (Twist)	0.1541
Moment Z	41.3019

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0279	2.2643	-0.0694	-0.2647	0.0505	-0.2921
ULS: 2. D + L	0.0279	2.2643	-0.0694	-0.2647	0.0505	-0.2921
ULS: 3. D + (S or Lr or R)	0.1058	6.8538	-0.2647	-1.0121	0.1939	-1.1747
ULS: 3. D + (S or Lr or R)	0.0279	2.2643	-0.0694	-0.2647	0.0505	-0.2921
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0863	5.7064	-0.2158	-0.8253	0.1580	-0.9540
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0279	2.2643	-0.0694	-0.2647	0.0505	-0.2921
ULS: 5b. D + 0.7E	0.0279	2.2643	-0.0694	-0.2647	0.0505	-0.2921
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0863	5.7064	-0.2158	-0.8253	0.1580	-0.9540
ULS: 8. 0.6D + 0.7E	0.0167	1.3586	-0.0416	-0.1588	0.0303	-0.1752
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5066	5.7921	-0.3142	-1.1680	0.7645	32.3783
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.5066	5.7921	-0.3142	-1.1680	0.7645	32.3783
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1589	-0.7073	0.1291	0.4656	-0.5278	-26.4909
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8333	-0.2285	0.1223	0.4401	-0.5168	-29.6122
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8145	8.3523	-0.3995	-1.5027	0.6936	23.5487
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8145	8.3523	-0.3995	-1.5027	0.6936	23.5487
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6846	3.4777	-0.0670	-0.2776	-0.2756	-20.6031
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4404	3.8368	-0.0721	-0.2967	-0.2674	-22.9441
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8730	4.9101	-0.2530	-0.9422	0.5860	24.2107
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8730	4.9101	-0.2530	-0.9422	0.5860	24.2107
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6261	0.0356	0.0795	0.2830	-0.3832	-19.9412
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3820	0.3947	0.0744	0.2639	-0.3750	-22.2822
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5178	4.8864	-0.2864	-1.0621	0.7443	32.4951
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.5178	4.8864	-0.2864	-1.0621	0.7443	32.4951
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1477	-1.6130	0.1569	0.5714	-0.5480	-26.3741
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8222	-1.1343	0.1501	0.5460	-0.5370	-29.4954

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.

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	13.0034
Shear X	-4.2242
Shear Z	-0.6070
Moment X	-2.3012
Moment Y (Twist)	1.3420
Moment Z	54.8143

Result	Value (kip, kip-ft)
Axial	8.3523
Shear X	-2.5178
Shear Z	-0.3995
Moment X	-1.5027
Moment Y (Twist)	0.7645
Moment Z	32.4951

Project Details

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

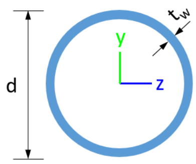
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

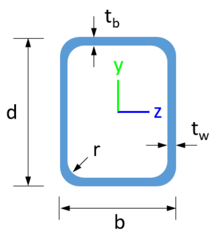
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

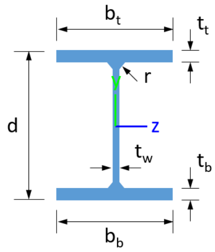
Section Dimensions



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



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



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

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

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

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	26.02	26.02	12.39	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.15,1.16,1.17,1.17,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.93,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.72,1.67,1.67,1.66,1.53	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.28,1.29,1.28,1.29,1.29,1.28,1.28,1.28,1.27,1.54,1.28,1.28,1.27,1.03,1.28,1.28,1.29,1.31,1.28,1.28,1.27,1.63,1.28,1.28,1.28,1.11	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.64	300	200	1
11	20	1.33	1.33	2.05	1.31,1.31,1.31,1.31,1.31,1.31,1.36,1.36,1.50,1.51,1.37,1.37,1.41,1.44,1.34,1.34,1.27,1.22,1.36,1.36,1.48,1.50,1.38,1.38,1.40,1.43	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.21,1.22,1.22,1.22,1.22,1.22,1.17,1.17,1.14,1.25,1.16,1.16,1.14,1.19,1.19,1.19,1.27,1.26,1.17,1.17,1.13,1.24,1.16,1.16,1.15,1.19	300	200	1
14	20	4.88	4.00	7.50	1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.21,1.18,1.63,1.20,1.20,1.20,1.76,1.21,1.21,1.23,1.27,1.21,1.21,1.19,1.70,1.20,1.20,1.20,1.52	300	200	1
15	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	26.02	26.02	12.39	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.63	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.08,2.08,2.05,2.13,2.08,2.08,2.07,1.96,2.09,2.09,2.14,2.10,2.08,2.08,2.06,2.13,2.08,2.08,2.07,2.07	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.59,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.64	300	200	1
111	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.77,1.77,1.40,1.47,1.72,1.72,1.58,1.59,1.98,1.98,2.39,2.27,1.78,1.78,1.43,1.49,1.70,1.70,1.61,1.62	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.09,1.20,1.27,1.10,1.10,1.12,1.14,1.08,1.08,1.05,1.03,1.09,1.09,1.18,1.25,1.10,1.10,1.11,1.12	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.10,1.30,1.07,1.07,1.08,1.12,1.06,1.06,1.05,1.05,1.07,1.07,1.10,1.38,1.07,1.07,1.08,1.10	300	200	1
115	20	6.63	6.63	10.20	1.14,1.14,1.14,1.14,1.14,1.14,1.11,1.11,1.07,1.08,1.11,1.11,1.09,1.09,1.12,1.12,1.17,1.21,1.11,1.11,1.07,1.08,1.11,1.11,1.10,1.10	300	200	1
116	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.14,1.14,1.14,1.14,1.32,1.15,1.15,1.16,1.15,1.15,1.15,1.14,1.13,1.14,1.14,1.14,1.22	300	200	1
201	9	26.02	26.02	12.39	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.57,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.63	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.10,2.11,2.10,2.10,2.10,2.10,2.08,2.10,2.10,2.09,2.09,2.10,2.10,2.11,2.10,2.10,2.10,2.10,2.09	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.57,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.63	300	200	1
211	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.06,2.06,1.58,1.72,2.02,2.02,1.84,1.89,2.08,2.08,2.34,2.27,2.06,2.06,1.62,1.75,2.00,2.00,1.88,1.92	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.03,1.03,1.03,1.04,1.03,1.03,1.04,1.04,1.05,1.05,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.03,1.04,1.04,1.05,1.05,1.04,1.04,1.04,1.04	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.03,1.03,1.24,1.03,1.03,1.04,1.02,1.04,1.04,1.04,1.04,1.03,1.03,1.03,1.30,1.03,1.03,1.03,1.02	300	200	1
215	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.12,1.13,1.14,1.14,1.14,1.14,1.16,1.16,1.19,1.21,1.15,1.15,1.12,1.13,1.14,1.14,1.14,1.14	300	200	1
216	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16	300	200	1
301	9	26.02	26.02	12.39	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.59,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.64	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
308	20	1.33	1.33	2.05	1.95,1.96,1.95,1.96,1.95,1.95,1.85,1.85,1.67,1.84,1.83,1.83,1.77,2.15,1.90,1.90,2.07,1.95,1.85,1.85,1.69,1.79,1.82,1.82,1.79,2.10	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.63	300	200	1
311	20	1.33	1.33	2.05	1.74,1.74,1.74,1.74,1.74,1.74,1.47,1.47,1.24,1.29,1.44,1.44,1.37,1.37,1.58,1.58,2.09,2.31,1.48,1.48,1.26,1.30,1.44,1.44,1.39,1.38	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.09,1.21,1.27,1.10,1.10,1.12,1.14,1.08,1.08,1.05,1.03,1.09,1.09,1.18,1.25,1.10,1.10,1.11,1.12	300	200	1
314	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.10,1.31,1.07,1.07,1.08,1.12,1.06,1.06,1.05,1.05,1.07,1.07,1.10,1.38,1.07,1.07,1.08,1.10	300	200	1

315	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.09,1.10,1.12,1.12,1.11,1.11,1.14,1.14,1.18,1.21,1.13,1.13,1.10,1.10,1.12,1.12,1.12,1.12	300	200	1
316	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.17,1.15,1.15,1.15,1.13,1.16,1.16,1.17,1.16,1.16,1.16,1.14,1.17,1.15,1.15,1.15,1.15	300	200	1
401	9	26.02	26.02	12.39	-	300	200	1
402	6	1.30	1.30	2.00	-	300	200	1
403	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
404	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.64	300	200	1
405	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
406	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.15,1.16,1.17,1.17,1.17,1.17	300	200	1
407	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
408	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	3	2.60	2.60	4.00	-	300	200	1
410	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.93,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.72,1.67,1.67,1.66,1.52	300	200	1
411	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	6	1.30	1.30	2.00	-	300	200	1
413	20	4.88	4.00	7.50	1.21,1.22,1.22,1.22,1.22,1.22,1.17,1.17,1.14,1.25,1.16,1.16,1.14,1.19,1.19,1.19,1.27,1.26,1.17,1.17,1.13,1.24,1.16,1.16,1.15,1.19	300	200	1
414	20	4.88	4.00	7.50	1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.21,1.18,1.63,1.20,1.20,1.20,1.78,1.22,1.22,1.23,1.27,1.21,1.21,1.19,1.69,1.20,1.20,1.20,1.52	300	200	1
415	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.12,1.12,1.09,1.09,1.10,1.11,1.08,1.08,1.08,1.09,1.09,1.09,1.12,1.12,1.09,1.09,1.10,1.10	300	200	1
416	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.11,1.08,1.08,1.08,1.11,1.08,1.08,1.09,1.08,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.07	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	165.51	83.29	83.29	113.39	113.39
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	34.52	6.46	56.26	44.91
14	159.30	97.43	36.10	6.46	56.26	44.91
15	159.30	113.66	46.90	6.46	56.26	44.91
16	159.30	113.66	46.90	6.46	56.26	44.91
101	377.97	165.51	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	31.56	6.46	56.26	44.91
114	159.30	97.43	31.94	6.46	56.26	44.91
115	159.30	75.13	20.64	6.46	56.26	44.91
116	159.30	75.13	21.83	6.46	56.26	44.91
201	377.97	165.51	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
213	159.30	97.43	31.46	6.46	56.26	44.91
214	159.30	97.43	31.03	6.46	56.26	44.91
215	159.30	75.13	21.60	6.46	56.26	44.91
216	159.30	75.13	22.21	6.46	56.26	44.91
301	377.97	165.51	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	140.46	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	140.46	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	31.55	6.46	56.26	44.91
314	159.30	97.43	31.94	6.46	56.26	44.91
315	159.30	75.13	21.07	6.46	56.26	44.91
316	159.30	75.13	21.84	6.46	56.26	44.91
401	377.97	165.51	83.29	83.29	113.39	113.39
402	251.01	248.88	27.16	27.16	75.30	75.30
403	151.65	150.70	20.17	14.14	54.12	28.95
404	151.65	145.15	20.17	14.14	54.12	28.95
405	151.65	149.10	20.17	14.14	54.12	28.95
406	151.65	150.70	20.17	14.14	54.12	28.95
407	151.65	149.10	20.17	14.14	54.12	28.95

407	151.65	149.10	20.17	14.14	54.12	28.95
408	159.30	113.66	46.90	6.46	56.26	44.91
409	75.10	66.32	4.25	4.25	22.53	22.53
410	151.65	145.15	20.17	14.14	54.12	28.95
411	159.30	113.66	46.90	6.46	56.26	44.91
412	251.01	248.88	27.16	27.16	75.30	75.30
413	159.30	97.43	34.53	6.46	56.26	44.91
414	159.30	97.43	36.13	6.46	56.26	44.91
415	159.30	75.13	20.85	6.46	56.26	44.91
416	159.30	75.13	20.59	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	0.079	0.658	0.063	0.037	0.005	0.718	#13	0.531	Not Required	Pass
2	0.003	0.273	0.127	0.066	0.025	0.363	#21	0.054	Not Required	Pass
3	0.007	0.447	0.029	0.043	0.003	0.470	#21	0.046	Not Required	Pass
4	0.006	0.440	0.084	0.044	0.022	0.526	#21	0.082	Not Required	Pass
5	0.006	0.277	0.065	0.044	0.017	0.292	#21	0.076	Not Required	Pass
6	0.012	0.626	0.114	0.063	0.031	0.745	#21	0.046	Not Required	Pass
7	0.013	0.388	0.204	0.062	0.051	0.433	#21	0.076	Not Required	Pass
8	0.005	0.116	0.217	0.036	0.024	0.242	#24	0.102	Not Required	Pass
9	0.009	0.062	0.087	0.003	0.005	0.133	#21	0.206	Not Required	Pass
10	0.013	0.591	0.191	0.059	0.042	0.691	#21	0.082	Not Required	Pass
11	0.007	0.112	0.225	0.038	0.024	0.247	#24	0.102	Not Required	Pass
12	0.001	0.465	0.176	0.101	0.032	0.590	#13	0.054	Not Required	Pass
13	0.010	0.103	0.563	0.050	0.031	0.588	#21	0.306	Not Required	Pass
14	0.006	0.093	0.551	0.047	0.031	0.589	#24	0.204	Not Required	Pass
15	0.000	0.016	0.054	0.013	0.008	0.070	#21	Not Required	Not Required	Pass
16	0.000	0.016	0.054	0.013	0.008	0.070	#21	Not Required	Not Required	Pass
101	0.103	0.849	0.007	0.048	0.001	0.894	#13	0.531	Not Required	Pass
102	0.004	0.488	0.199	0.110	0.034	0.639	#21	0.036	Not Required	Pass
103	0.012	0.697	0.074	0.069	0.010	0.778	#21	0.046	Not Required	Pass
104	0.012	0.707	0.210	0.070	0.045	0.852	#21	0.082	Not Required	Pass
105	0.012	0.433	0.218	0.069	0.056	0.488	#21	0.076	Not Required	Pass
106	0.012	0.708	0.073	0.070	0.010	0.781	#21	0.046	Not Required	Pass
107	0.012	0.440	0.205	0.070	0.053	0.495	#21	0.076	Not Required	Pass
108	0.005	0.046	0.212	0.040	0.024	0.243	#21	0.102	Not Required	Pass
109	0.020	0.059	0.053	0.001	0.000	0.113	#21	0.206	Not Required	Pass
110	0.012	0.701	0.198	0.070	0.043	0.836	#21	0.082	Not Required	Pass
111	0.007	0.065	0.220	0.040	0.024	0.242	#24	0.102	Not Required	Pass
112	0.004	0.491	0.207	0.110	0.038	0.645	#21	0.036	Not Required	Pass
113	0.010	0.187	0.592	0.054	0.032	0.742	#21	0.306	Not Required	Pass
114	0.010	0.219	0.586	0.056	0.032	0.769	#21	0.306	Not Required	Pass
115	0.013	0.361	0.304	0.043	0.025	0.670	#21	0.507	Not Required	Pass
116	0.005	0.340	0.301	0.045	0.025	0.642	#21	0.507	Not Required	Pass
201	0.101	0.860	0.000	0.048	0.000	0.903	#13	0.531	Not Required	Pass
202	0.004	0.484	0.202	0.108	0.036	0.633	#21	0.036	Not Required	Pass
203	0.012	0.702	0.072	0.070	0.010	0.780	#21	0.046	Not Required	Pass
204	0.012	0.682	0.194	0.068	0.042	0.817	#21	0.082	Not Required	Pass
205	0.012	0.436	0.203	0.069	0.052	0.489	#21	0.076	Not Required	Pass

206	0.012	0.702	0.072	0.070	0.010	0.780	#21	0.046	Not Required	Pass
207	0.012	0.436	0.203	0.069	0.052	0.489	#21	0.076	Not Required	Pass
208	0.005	0.046	0.209	0.040	0.024	0.245	#21	0.102	Not Required	Pass
209	0.019	0.053	0.051	0.001	0.000	0.112	#21	0.206	Not Required	Pass
210	0.012	0.682	0.194	0.068	0.042	0.817	#21	0.082	Not Required	Pass
211	0.007	0.057	0.215	0.041	0.024	0.250	#21	0.102	Not Required	Pass
212	0.004	0.484	0.202	0.108	0.036	0.633	#21	0.036	Not Required	Pass
213	0.010	0.216	0.550	0.053	0.031	0.748	#21	0.306	Not Required	Pass
214	0.010	0.222	0.542	0.052	0.031	0.739	#21	0.306	Not Required	Pass
215	0.013	0.263	0.304	0.041	0.024	0.565	#21	0.507	Not Required	Pass
216	0.007	0.233	0.300	0.040	0.024	0.534	#21	0.507	Not Required	Pass
301	0.103	0.849	0.007	0.048	0.001	0.894	#13	0.531	Not Required	Pass
302	0.004	0.491	0.207	0.110	0.038	0.645	#21	0.036	Not Required	Pass
303	0.012	0.708	0.073	0.070	0.010	0.781	#21	0.046	Not Required	Pass
304	0.012	0.701	0.198	0.070	0.043	0.835	#21	0.082	Not Required	Pass
305	0.012	0.440	0.205	0.070	0.053	0.495	#21	0.076	Not Required	Pass
306	0.012	0.697	0.074	0.069	0.010	0.778	#21	0.046	Not Required	Pass
307	0.012	0.433	0.218	0.068	0.056	0.488	#21	0.076	Not Required	Pass
308	0.005	0.072	0.243	0.045	0.025	0.264	#21	0.102	Not Required	Pass
309	0.020	0.059	0.053	0.001	0.000	0.113	#21	0.206	Not Required	Pass
310	0.012	0.707	0.210	0.070	0.045	0.852	#21	0.082	Not Required	Pass
311	0.007	0.094	0.248	0.043	0.025	0.252	#21	0.102	Not Required	Pass
312	0.004	0.489	0.199	0.110	0.034	0.639	#21	0.036	Not Required	Pass
313	0.010	0.187	0.593	0.054	0.032	0.743	#21	0.306	Not Required	Pass
314	0.010	0.219	0.586	0.056	0.032	0.769	#21	0.306	Not Required	Pass
315	0.013	0.266	0.305	0.040	0.024	0.569	#21	0.507	Not Required	Pass
316	0.007	0.233	0.300	0.040	0.024	0.534	#21	0.507	Not Required	Pass
401	0.079	0.658	0.062	0.037	0.005	0.718	#13	0.531	Not Required	Pass
402	0.001	0.465	0.176	0.101	0.032	0.590	#13	0.054	Not Required	Pass
403	0.012	0.626	0.114	0.063	0.031	0.745	#21	0.046	Not Required	Pass
404	0.013	0.591	0.191	0.059	0.042	0.691	#21	0.082	Not Required	Pass
405	0.013	0.388	0.204	0.062	0.051	0.433	#21	0.076	Not Required	Pass
406	0.007	0.447	0.029	0.043	0.003	0.470	#21	0.046	Not Required	Pass
407	0.006	0.277	0.065	0.044	0.017	0.292	#21	0.076	Not Required	Pass
408	0.000	0.016	0.054	0.013	0.008	0.070	#21	Not Required	Not Required	Pass
409	0.009	0.062	0.087	0.003	0.005	0.133	#21	0.206	Not Required	Pass
410	0.006	0.440	0.084	0.044	0.022	0.526	#21	0.082	Not Required	Pass
411	0.000	0.016	0.054	0.013	0.008	0.070	#21	Not Required	Not Required	Pass
412	0.003	0.273	0.127	0.066	0.025	0.363	#21	0.054	Not Required	Pass
413	0.010	0.103	0.562	0.050	0.031	0.588	#21	0.204	Not Required	Pass
414	0.006	0.092	0.552	0.047	0.031	0.589	#24	0.306	Not Required	Pass
415	0.013	0.371	0.304	0.038	0.024	0.678	#21	0.507	Not Required	Pass
416	0.005	0.362	0.298	0.036	0.024	0.655	#21	0.507	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength

A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

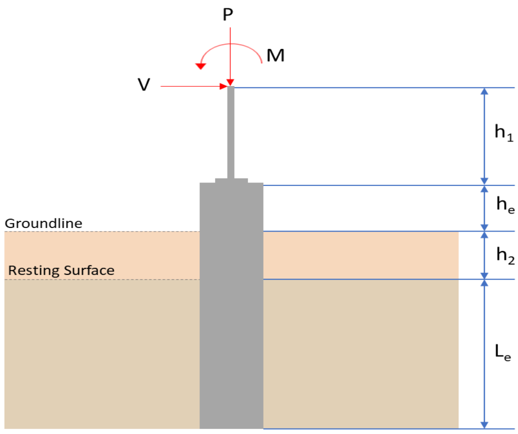
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 6.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.352	13.003
V_x (kip)	-2.518	-4.224
V_z (kip)	0.399	0.607
M_x (kipft)	1.503	2.300
M_z (kipft)	32.495	54.813

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,

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

$$H_o = \frac{(-2.518\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.40096\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.495\text{ kipft}) + ((-2.518\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 5.1744\text{ kipft/ft}$$

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:
$L_{e,x} = 6.3852\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.399\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.063535\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.503\text{ kipft}) + ((0.399\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.23933\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.1461\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3852\text{ ft}), (3.1461\text{ ft})]$$

$$L_{e,req} = 6.385\text{ ft}$$

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

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

$$Ratio = \frac{(6.385\text{ ft})}{(6.75\text{ ft})}$$

$$Ratio = 0.94593$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.352\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.522\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.522\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.261$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.40096\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.1744\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1744\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.40096\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (5.1744\ \mathrm{kipft/ft})) + (4 \times (-0.40096\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6454\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1744\ \mathrm{kipft/ft})) + (3 \times (-0.40096\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (5.1744\ \mathrm{kipft/ft})) + (2 \times (-0.40096\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.25759\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1744\ \mathrm{kipft/ft})) + ((-0.40096\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 1.0064\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6454\ \mathrm{ft})}{2}$$

$$p_a = 0.34841\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.25759\ \mathrm{kip/ft^2}\right)}{\left(0.34841\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.73933$$	Status: **PASS** Ratio: **0.740**
	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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.0064\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.99397$$	Status: **PASS** Ratio: **0.990**
	Considering z-direction: $H_o = 0.063535\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.23933\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.23933\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.23933\ \mathrm{kipft/ft})) + (4 \times (0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$ $$a = 4.8062\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.23933\ \mathrm{kipft/ft})) + (3 \times (0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.23933\ \mathrm{kipft/ft})) + (2 \times (0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$ $$p = 0.0526\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.23933\ \mathrm{kipft/ft})) + ((0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})]}{(6.75\ \mathrm{ft})^2}$$ $$s = 0.11951\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8062\ \mathrm{ft})}{2}$$ $$p_a = 0.36046\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0526\ \mathrm{kip/ft^2}\right)}{\left(0.36046\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.14592$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

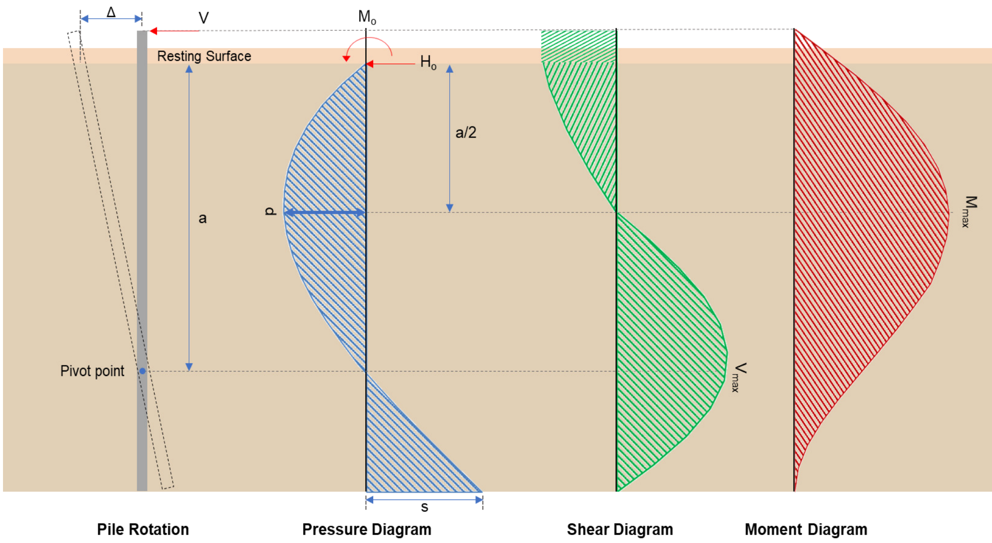
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.11951\ \text{kip/ft}^2\right)}{\left(1.0125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.11803$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.224\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.67261\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.813\ \text{kipft}) + ((-4.224\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.7282\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.7282\ \text{kipft/ft})}{(-0.67261\ \text{kip/ft})}$$

$$E = 12.977\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7282\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.67261\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{}$$

$$a = \frac{\ldots}{(6 \times (8.7282\ \text{kipft/ft})) + (4 \times (-0.67261\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6448\ \text{ft}$$

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

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

$$V_{max} = ((-0.67261\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6448\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6448\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.928\ \text{kip}$$

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

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

$$M_{max} = ((-0.67261\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(12.977\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 35.231\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.607\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.096656\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.3\ \text{kipft}) + ((0.607\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.36624\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.36624\ \text{kipft/ft})}{(0.096656\ \text{kip/ft})}$$

$$E = 3.7891\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.36624\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (0.096656\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (0.36624\ \text{kipft/ft})) + (4 \times (0.096656\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.8054\ \text{ft}$$

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

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

$$V_{max} = ((0.096656 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7891 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8054 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.7891 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8054 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.64119 \text{ kip}$$

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

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

$$M_{max} = ((0.096656 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(3.7891 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8054 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.7891 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8054 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.7891 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8054 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.9309 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.003 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

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

A_{min} - Governing minimum reinforcement area,

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

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

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.003\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0048606$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.003 \text{ kip} \rightarrow 13003 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13003 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

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

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

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

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

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

V_c - Governing shear strength of concrete

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

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

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

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

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

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

Considering x-direction:

$V_{max} = 10.928 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.928 \text{ kip})}{(111.22 \text{ kip})}$$ $$Ratio = 0.098253$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.64119 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.64119 \text{ kip})}{(111.22 \text{ kip})}$$ $$Ratio = 0.0057649$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 35.231 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(35.231 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.14115$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $M_{max} = 1.9309 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.9309\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0077359$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

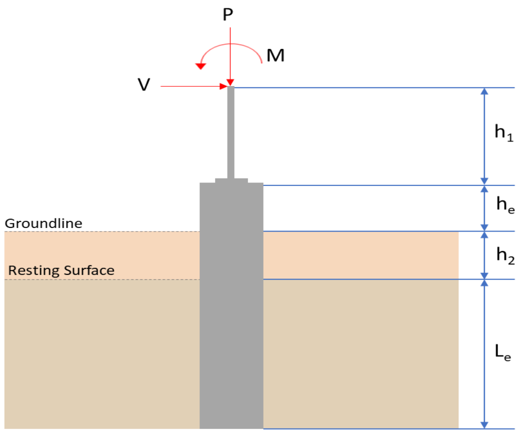
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ 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)	8.352	13.003
V_x (kip)	-2.518	-4.224
V_z (kip)	-0.399	-0.607
M_x (kipft)	-1.503	-2.301
M_z (kipft)	32.495	54.814

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,

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

$$H_o = \frac{(-2.518\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.40096\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(32.495 \text{ kipft}) + ((-2.518 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.1744 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.3852 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.399 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.063535 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.503 \text{ kipft}) + ((-0.399 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23933 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.206 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3852 \text{ ft}), (2.206 \text{ ft})]$$

$$L_{e,req} = 6.385 \text{ ft}$$

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

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

$$Ratio = \frac{(6.385 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.94593$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.352 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.522 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.522 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.261$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.40096 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.1744 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.1744 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.40096 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (5.1744 \text{ kipft/ft})) + (4 \times (-0.40096 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6454 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.1744 \text{ kipft/ft})) + (3 \times (-0.40096 \text{ kip/ft}) \times (6.75 \text{ ft})]^{\;2}}{(6.75 \text{ ft})^2 \times [(3 \times (5.1744 \text{ kipft/ft})) + (2 \times (-0.40096 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.25759 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.1744 \text{ kipft/ft})) + ((-0.40096 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 1.0064 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6454 \text{ ft})}{2}$$

$$p_a = 0.34841 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25759\ \mathrm{kip/ft^2}\right)}{\left(0.34841\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.73933$$

Status: **PASS**
Ratio: **0.740**

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

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

$$Ratio = \frac{\left(1.0064\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.99397$$

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = -0.063535\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.23933\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23933\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.23933\ \mathrm{kipft/ft})) + (4 \times (-0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8062\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.23933\ \mathrm{kipft/ft})) + (3 \times (-0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\,2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.23933\ \mathrm{kipft/ft})) + (2 \times (-0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.012772\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.23933\ \mathrm{kipft/ft})) + ((-0.063535\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.0065582\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8062\ \mathrm{ft})}{2}$$

$$p_a = 0.36046\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.012772\ \mathrm{kip/ft^2}\right)}{\left(0.36046\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.035431$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

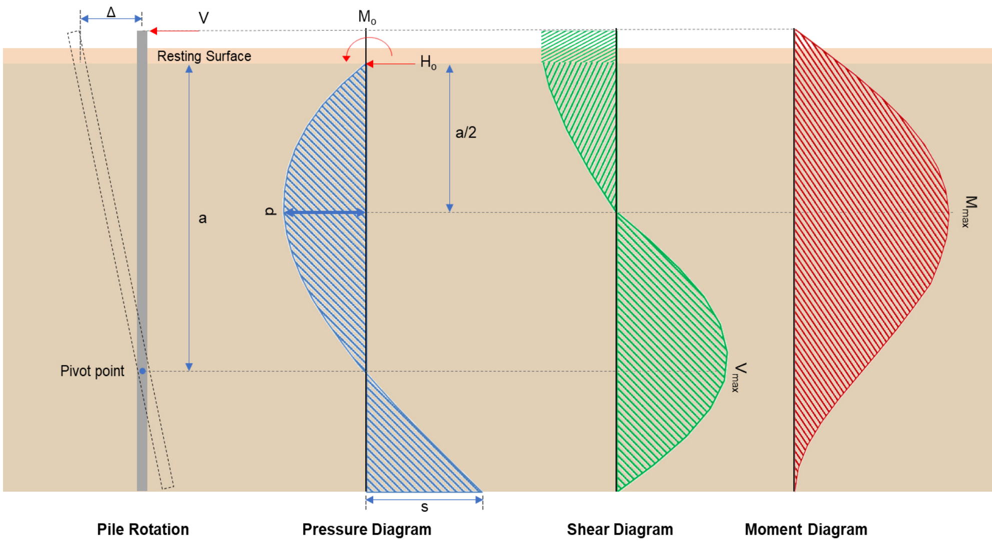
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0065582\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0064772$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.224\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.67261\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.814\ \mathrm{kipft}) + ((-4.224\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.7283\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.7283\ \mathrm{kipft/ft})}{(-0.67261\ \mathrm{kip/ft})}$$

$$E = 12.977\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7283\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.67261\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (8.7283\ \text{kipft/ft})) + (4 \times (-0.67261\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6448\ \text{ft}$$

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

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

$$V_{max} = ((-0.67261\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6448\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6448\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.928\ \text{kip}$$

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

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

$$M_{max} = ((-0.67261\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(12.977\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.977\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6448\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 35.231\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.607\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.096656\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.301\ \text{kipft}) + ((-0.607\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.3664\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.3664\ \text{kipft/ft})}{(-0.096656\ \text{kip/ft})}$$

$$E = 3.7908\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.3664\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.096656\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (0.3664\ \text{kipft/ft})) + (4 \times (-0.096656\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.8053\ \text{ft}$$

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

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

$$V_{max} = ((-0.096656 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7908 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8053 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.7908 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8053 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.64135 \text{ kip}$$

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

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

$$M_{max} = ((-0.096656 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(3.7908 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8053 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.7908 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8053 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.7908 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8053 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.9314 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.003 \text{ kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

A_{min} - Governing minimum reinforcement area,

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

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

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	Status: PASS Ratio: 0.970
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$ $$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\ \text{in}))\right]$$ $$s_{rebar} = 1.5\ \text{in}$$ **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, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\left(D, b\right)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min\left((48\ \text{in}), (48\ \text{in})\right)\right]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left(\left(60\ \text{ksi}\right) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.003\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0048606$$	Status: PASS Ratio: 0.000
22.5.2.2 22.5.5.1.3 22.5.5.1.1	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.003 \text{ kip} \rightarrow 13003 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13003 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

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

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

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

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

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

V_c - Governing shear strength of concrete

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

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

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

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

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

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

Considering x-direction:

$V_{max} = 10.928 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.928\ \text{kip})}{(111.22\ \text{kip})}$$

$$Ratio = 0.098254$$

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

Considering z-direction:

$V_{max} = 0.64135\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.64135\ \text{kip})}{(111.22\ \text{kip})}$$

$$Ratio = 0.0057664$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 35.231\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(35.231\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.14115$$

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

Considering z-direction:

$M_{max} = 1.9314\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.9314\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0077381$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

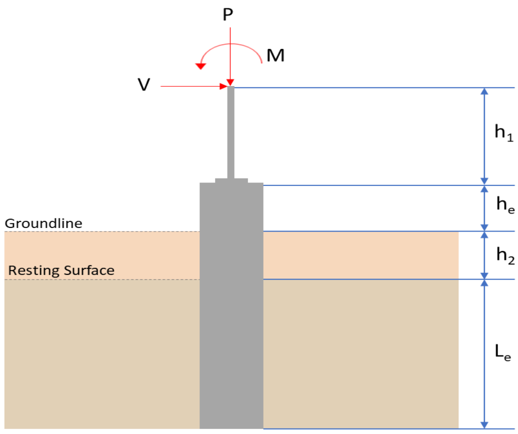
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.883	17.008
V_x (kip)	-3.247	-5.429
V_z (kip)	-0.038	-0.071
M_x (kipft)	-0.141	-0.258
M_z (kipft)	41.302	70.730

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.247\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.51704\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.302\ \text{kipft}) + ((-3.247\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.5768\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.8044\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.038\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.006051\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.141\ \text{kipft}) + ((-0.038\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.022452\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.1162\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8044\ \text{ft}), (1.1162\ \text{ft})]$$

$$L_{e,req} = 6.804\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.804\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.93848$$

Status: **PASS**
Ratio: **0.940**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.883\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.68019\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68019\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.34009$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.51704\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5768\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5768\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.51704\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (6.5768\ \mathrm{kipft/ft})) + (4 \times (-0.51704\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9997\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5768\ \mathrm{kipft/ft})) + (3 \times (-0.51704\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (6.5768\ \mathrm{kipft/ft})) + (2 \times (-0.51704\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.26459\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5768\ \mathrm{kipft/ft})) + ((-0.51704\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 1.0736\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9997\ \mathrm{ft})}{2}$$

$$p_a = 0.37498\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.26459\ \mathrm{kip/ft^2}\right)}{\left(0.37498\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.70562$$	Status: **PASS** Ratio: **0.710**	
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$ $$p_s = 1.0875\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.0736\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.9872$$	Status: **PASS** Ratio: **0.990**	
	Considering z-direction: $H_o = -0.006051\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.022452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.022452\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.022452\ \mathrm{kipft/ft})) + (4 \times (-0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$ $$a = 5.1751\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.022452\ \mathrm{kipft/ft})) + (3 \times (-0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.022452\ \mathrm{kipft/ft})) + (2 \times (-0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$ $$p = -0.0012231\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.022452\ \mathrm{kipft/ft})) + ((-0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$ $$s = 0.00011815\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1751\ \mathrm{ft})}{2}$$ $$p_a = 0.38813\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.0012231\ \mathrm{kip/ft^2}\right)}{\left(0.38813\ \mathrm{kip/ft^2}\right)}$$		

$$Ratio = -0.0031513$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

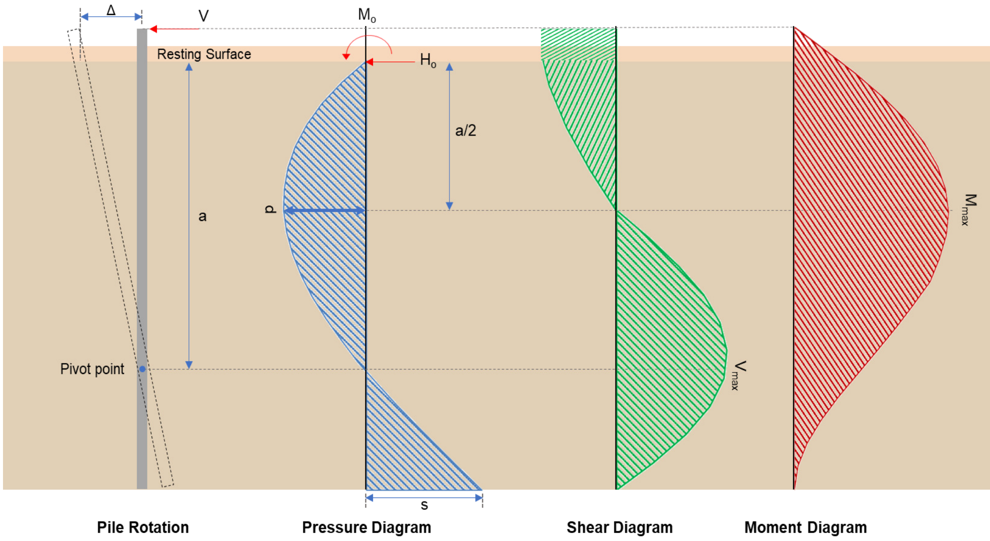
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00011815\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00010864$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.429\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.86449\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70.73\ \mathrm{kipft}) + ((-5.429\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.263\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.263\ \mathrm{kipft/ft})}{(-0.86449\ \mathrm{kip/ft})}$$

$$E = 13.028\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.263\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.86449\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (11.263\ \mathrm{kipft/ft})) + (4 \times (-0.86449\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9968\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.86449\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.028\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.9968\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.028\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.9968\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.277\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.86449\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.25\ \mathrm{ft})) \times \left[\left(\frac{(13.028\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + \frac{(4.9968\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (13.028\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.9968\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.028\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.9968\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 45.851\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.071\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.011306\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.258\ \mathrm{kipft}) + ((-0.071\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.041083\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.041083\ \mathrm{kipft/ft})}{(-0.011306\ \mathrm{kip/ft})}$$

$$E = 3.6338\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.041083\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.011306\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.041083\ \mathrm{kipft/ft})) + (4 \times (-0.011306\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1782\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.011306 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1782 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1782 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.070238 \text{ kip}$$

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

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

$$M_{max} = ((-0.011306 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(3.6338 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.22537 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(17.008 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.031 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.031 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

$$Ratio = \frac{(17.008 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0063577$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.008 \text{ kip} \rightarrow 17008 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17008 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.75 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.75 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.75 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.75 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.57 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.277 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.277\ \text{kip})}{(111.57\ \text{kip})}$$

$$Ratio = 0.119$$

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

Considering z-direction:

$V_{max} = 0.070238\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.070238\ \text{kip})}{(111.57\ \text{kip})}$$

$$Ratio = 0.00062954$$

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:

$M_{max} = 45.851\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(45.851\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.1837$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$M_{max} = 0.22537\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.22537\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00090291$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

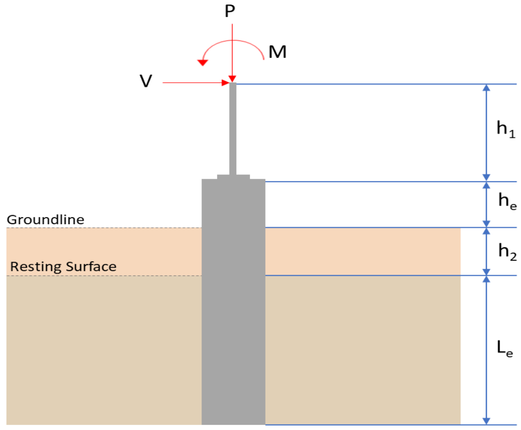
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7.25\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.883	17.008
V_x (kip)	-3.247	-5.429
V_z (kip)	0.038	0.071
M_x (kipft)	0.141	0.258
M_z (kipft)	41.302	70.731

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,

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

$$H_o = \frac{(-3.247\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.51704\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.302\ \mathrm{kipft}) + ((-3.247\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.5768\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.8044\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.038\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.006051\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.141\ \mathrm{kipft}) + ((0.038\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.022452\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.3149\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8044\ \mathrm{ft}), (1.3149\ \mathrm{ft})]$$

$$L_{e,req} = 6.804\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 7.25\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.804\ \mathrm{ft})}{(7.25\ \mathrm{ft})}$$

$$Ratio = 0.93848$$

Status: **PASS**
Ratio: **0.940**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.883\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.68019\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68019\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.34009$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.51704\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5768\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5768\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.51704\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (6.5768\ \text{kipft/ft})) + (4 \times (-0.51704\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9997\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5768\ \text{kipft/ft})) + (3 \times (-0.51704\ \text{kip/ft}) \times (7.25\ \text{ft}))]^2}{(7.25\ \text{ft})^2 \times [(3 \times (6.5768\ \text{kipft/ft})) + (2 \times (-0.51704\ \text{kip/ft}) \times (7.25\ \text{ft}))]}$$

$$p = 0.26459\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5768\ \text{kipft/ft})) + ((-0.51704\ \text{kip/ft}) \times (7.25\ \text{ft}))]}{(7.25\ \text{ft})^2}$$

$$s = 1.0736\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.9997\ \text{ft})}{2}$$

$$p_a = 0.37498\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26459\ \mathrm{kip/ft^2}\right)}{\left(0.37498\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.70562$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0736\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9872$$

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = 0.006051\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.022452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.022452\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.022452\ \mathrm{kipft/ft})) + (4 \times (0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1751\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.022452\ \mathrm{kipft/ft})) + (3 \times (0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.022452\ \mathrm{kipft/ft})) + (2 \times (0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.0045103\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.022452\ \mathrm{kipft/ft})) + ((0.006051\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.010134\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1751\ \mathrm{ft})}{2}$$

$$p_a = 0.38813\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0045103\ \mathrm{kip/ft^2}\right)}{\left(0.38813\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.011621$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

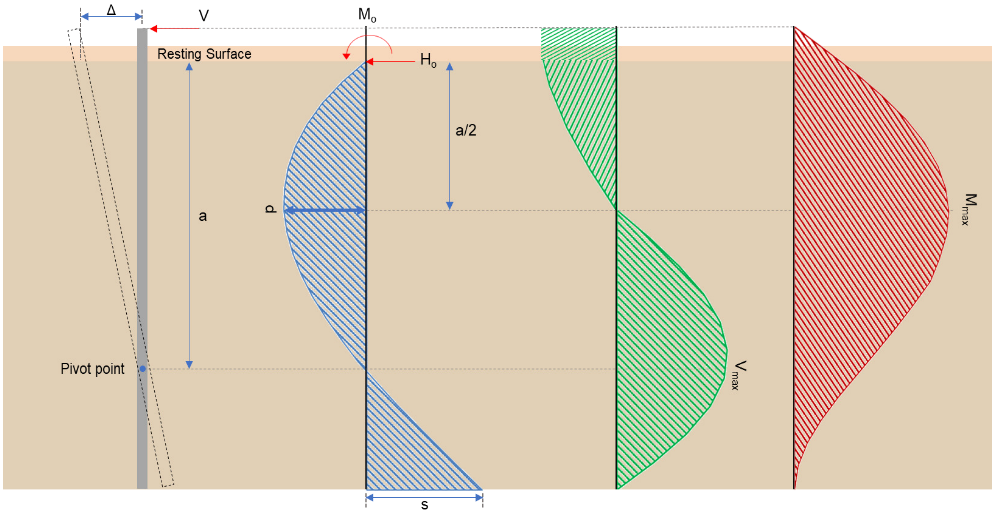
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.010134\ \mathrm{kip/ft^2})}{(1.0875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0093182$$

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



Pile Rotation
Pressure Diagram
Shear Diagram
Moment Diagram

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.429\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.86449\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70.731\ \mathrm{kipft}) + ((-5.429\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.263\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.263\ \mathrm{kipft/ft})}{(-0.86449\ \mathrm{kip/ft})}$$

$$E = 13.028\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.263\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.86449\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (11.263\ \text{kipft/ft})) + (4 \times (-0.86449\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9968\ \text{ft}$$

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

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

$$V_{max} = ((-0.86449\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.028\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9968\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.028\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9968\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.277\ \text{kip}$$

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

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

$$M_{max} = ((-0.86449\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(13.028\ \text{ft})}{(7.25\ \text{ft})} + \frac{(4.9968\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (13.028\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9968\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.028\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9968\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 45.852\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.071\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.011306\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.258\ \text{kipft}) + ((0.071\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.041083\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.041083\ \text{kipft/ft})}{(0.011306\ \text{kip/ft})}$$

$$E = 3.6338\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.041083\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (0.011306\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (0.041083\ \text{kipft/ft})) + (4 \times (0.011306\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.1782\ \text{ft}$$

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

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

$$V_{max} = ((0.011306 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1782 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1782 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.070238 \text{ kip}$$

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

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

$$M_{max} = ((0.011306 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(3.6338 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.6338 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1782 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.22537 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(17.008 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.031 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.031 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.008\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0063577$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\; D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.008 \text{ kip} \rightarrow 17008 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17008 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.75 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.75 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.75 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.75 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.57 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.277 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(13.277\ \text{kip})}{(111.57\ \text{kip})}$$ $$Ratio = 0.119$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $V_{max} = 0.070238\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.070238\ \text{kip})}{(111.57\ \text{kip})}$$ $$Ratio = 0.00062954$$	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:** $M_{max} = 45.852\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(45.852\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.1837$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.22537\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.22537\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00090291$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

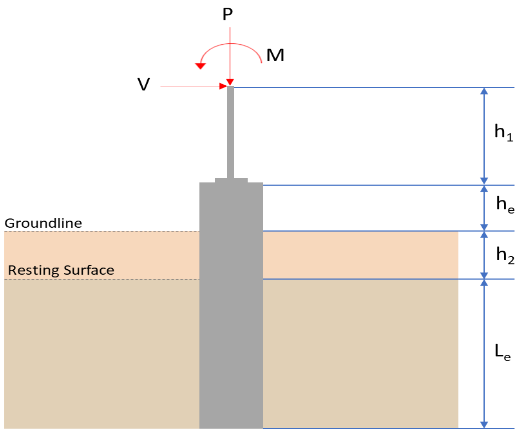
SkyCiv Foundation Design

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
$L = 7.5$ 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)	10.734	16.761
V_x (kip)	-3.248	-5.419
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	41.880	71.654

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,

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

$$H_o = \frac{(-3.248 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.5172 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.88 \text{ kipft}) + ((-3.248 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6688 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.8472 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

$L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8472 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 6.847 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.847 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.91293$$

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

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

$$q = \frac{(10.734 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.67087 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.67087 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.33544$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.5172\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.6688\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.6688\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.5172\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.6688\ \mathrm{kipft/ft})) + (4 \times (-0.5172\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1746\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.6688\ \mathrm{kipft/ft})) + (3 \times (-0.5172\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.6688\ \mathrm{kipft/ft})) + (2 \times (-0.5172\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.24618\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.6688\ \mathrm{kipft/ft})) + ((-0.5172\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0089\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1746\ \mathrm{ft})}{2}$$

$$p_a = 0.3881\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24618\ \mathrm{kip/ft^2}\right)}{\left(0.3881\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.63432$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

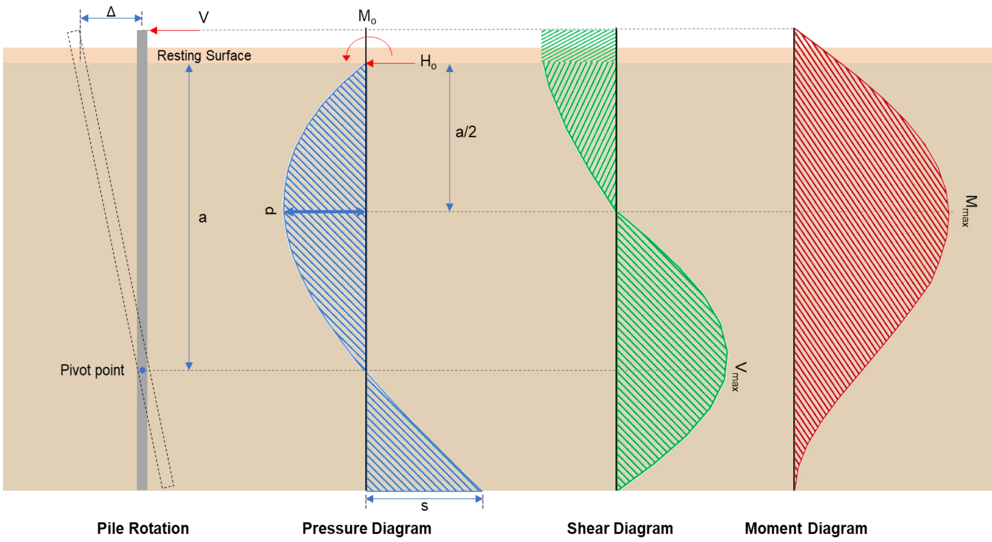
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0089\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89682$$

Status: PASS
Ratio: 0.900



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.419\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.8629\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(71.654\text{ kipft}) + ((-5.419\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 11.41\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.41\text{ kipft/ft})}{(-0.8629\text{ kip/ft})}$$

$$E = 13.223\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.41\text{ kipft/ft}) \times (7.5\text{ ft})) + \left(3 \times (-0.8629\text{ kip/ft}) \times (7.5\text{ ft})^2\right)}{(6 \times (11.41\text{ kipft/ft})) + (4 \times (-0.8629\text{ kip/ft}) \times (7.5\text{ ft}))}$$

$$a = 5.1715\text{ ft}$$

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

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

$$V_{max} = ((-0.8629\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.223\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.1715\text{ ft})}{(7.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.223\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.1715\text{ ft})}{(7.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 13.045\text{ kip}$$

$V_{max} = 13.045 \text{ kip}$

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

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

$$M_{max} = ((-0.8629 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(13.223 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1715 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (13.223 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.1715 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.223 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.1715 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 46.567 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(16.761 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.039 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.039 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

	$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\ \text{in}))\right]$ $s_{rebar} = 1.5\ \text{in}$ **Ties:**	
25.7.2.2	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)	
25.7.2.1	s_{ties} - Maximum spacing of ties, $s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$ $s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min\,((48\ \text{in}), (48\ \text{in}))\right]$ $s_{ties} = 10\ \text{in}$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$ $\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$ $\phi P_N = 2675.2\ \text{kip}$ $Ratio$ - Capacity $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(16.761\ \text{kip})}{(2675.2\ \text{kip})}$ $Ratio = 0.0062654$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $d = 0.80\ D$ $d = 0.80 \times (48\ \text{in})$ $d = 38.4\ \text{in}$	
22.5.5.1.3	λ_s - size effect modification factor $\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$ $\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$ $\lambda_s = 0.64282$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$ $V_{c,max} = 296.21\ \text{kip}$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.761\ \text{kip} \rightarrow 16761\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$	

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(16761\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.72\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.72\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.72\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.72\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.55\ \text{kip}$$

Considering x-direction:

$V_{max} = 13.045\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.045\ \text{kip})}{(111.55\ \text{kip})}$$

$$Ratio = 0.11694$$

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

	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:** $M_{max} = 46.567\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(46.567\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.18656$$	Status: **PASS** Ratio: **0.190**