Project Details

Project Name: Elmira Corning Regional Airport - 590w - 4x12 -5P1975 - V1Jb

Location: 276 Sing Sing Rd #1, Horseheads, NY 14845, USA

Unique ID: 5P-19.75-8TOP-HD-24-L-4Hx12W-2KIB

Dealer: ______________________________

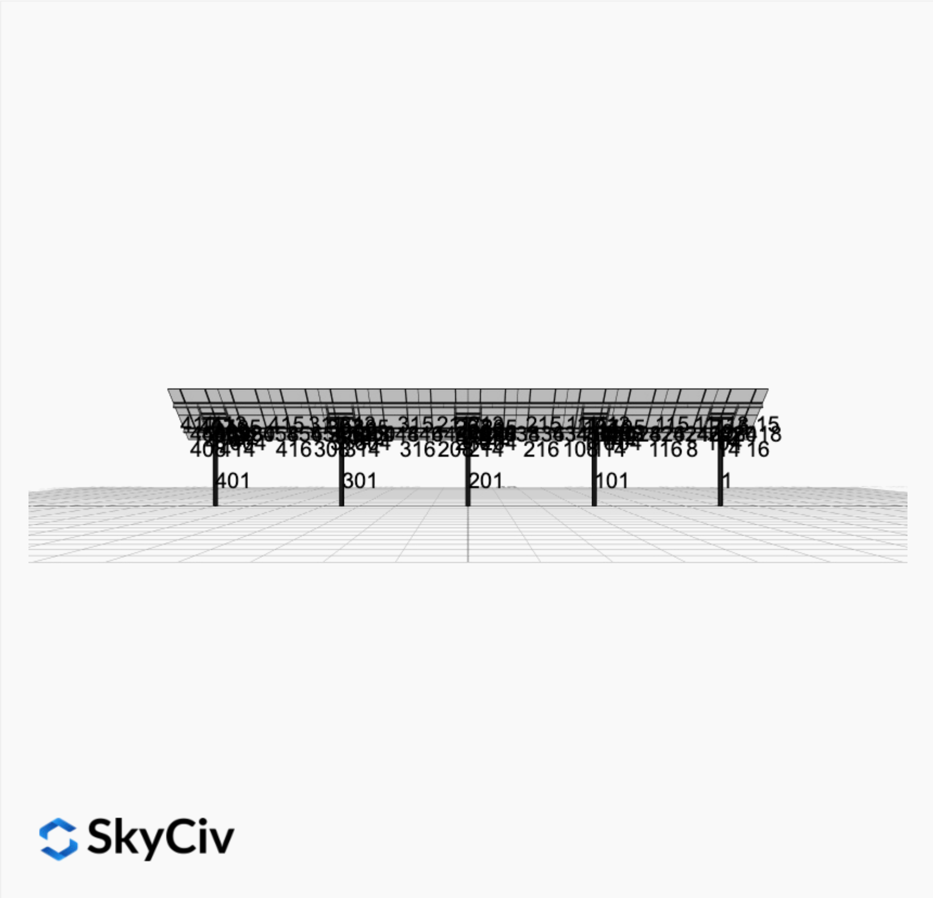
Date: Mon Feb 03 2025

Number of Modules: 48

Number of Poles: 5

Date Sold:

____



Array Dimensions N/S	15.03 ft
Array Dimensions E/W	90.70 ft
Winter Tilt Angle	30
Front Edge Clearance	10 ft

MT Solar Bill of Materials (5P-19.75-8TOP-HD-24-L-4Hx12W-2KIB)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	5
MTS-HF-HD	H-Frame Assembly-HD	5
MTS-HD-Wing-24	24IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	8
MTS-HD-Splice-57	57IN HD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (178in)	24
Rail Attachment	48

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

Site Details:

Site Address: 276 Sing Sing Rd #1, Horseheads, NY 14845, USA

Array Specification

Duty Classification:	HD
Module Width:	44.60 in
Module Length:	89.70in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	30
Front Edge Clearance:	10
Total Array Height at Tilt:	17.52 ft
Total Frame Length:	90.50 ft
Frame Weight:	5864 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	90.70 ft
Rail Length:	180.40 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	13.76 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: 6.25 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 6.75 ft Pile 5: 6.25 ft
Foundation Volume:	19.407 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	276 Sing Sing Rd #1, Horseheads, NY 14845, USA
Wind Speed:	103 mph
Snow Load:	50 psf

Design Disclaimer

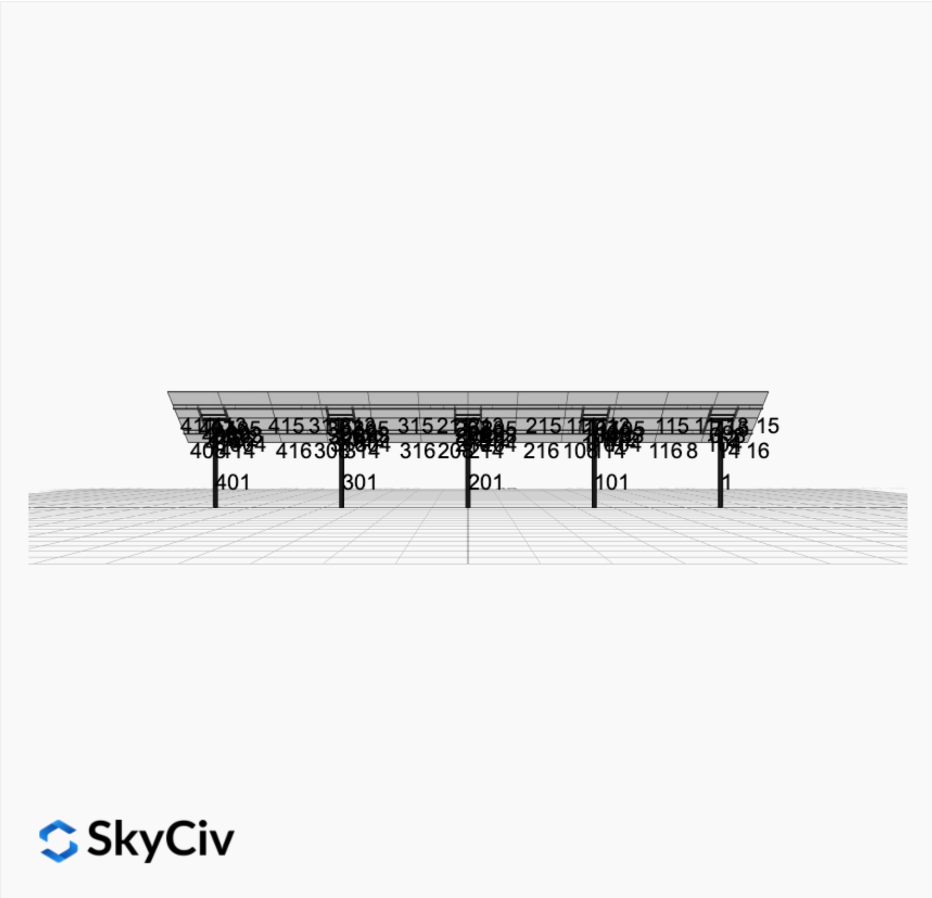
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

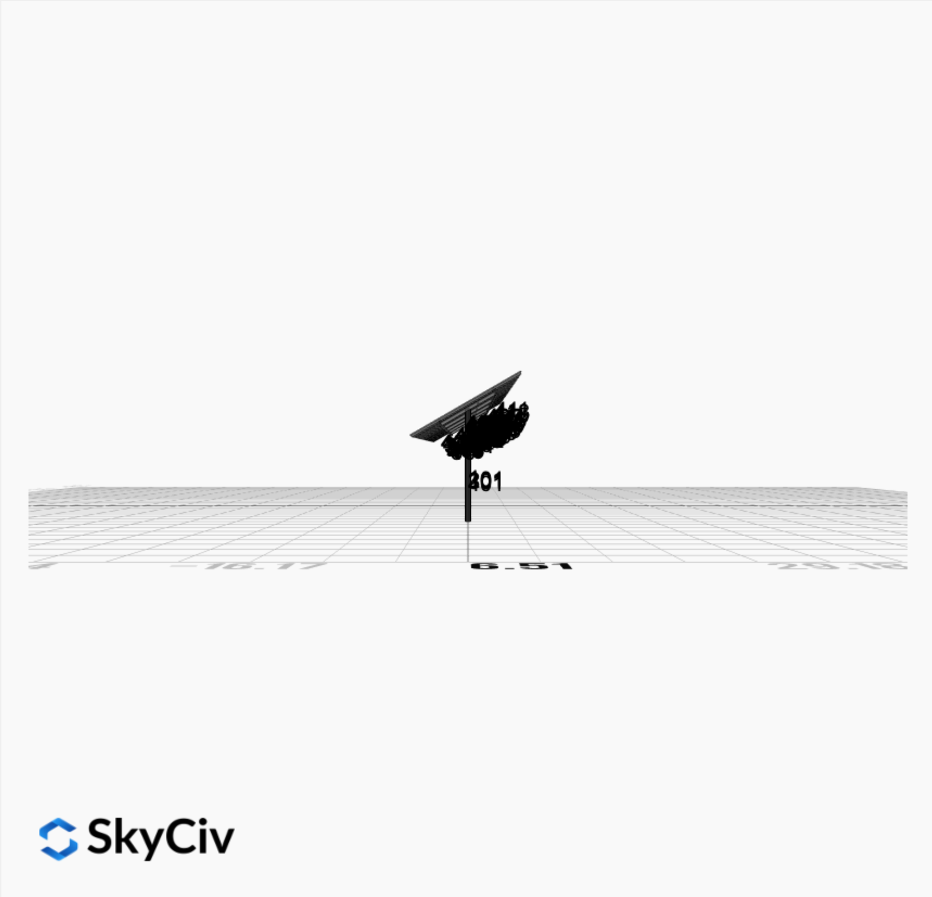
AutoDesigner Input

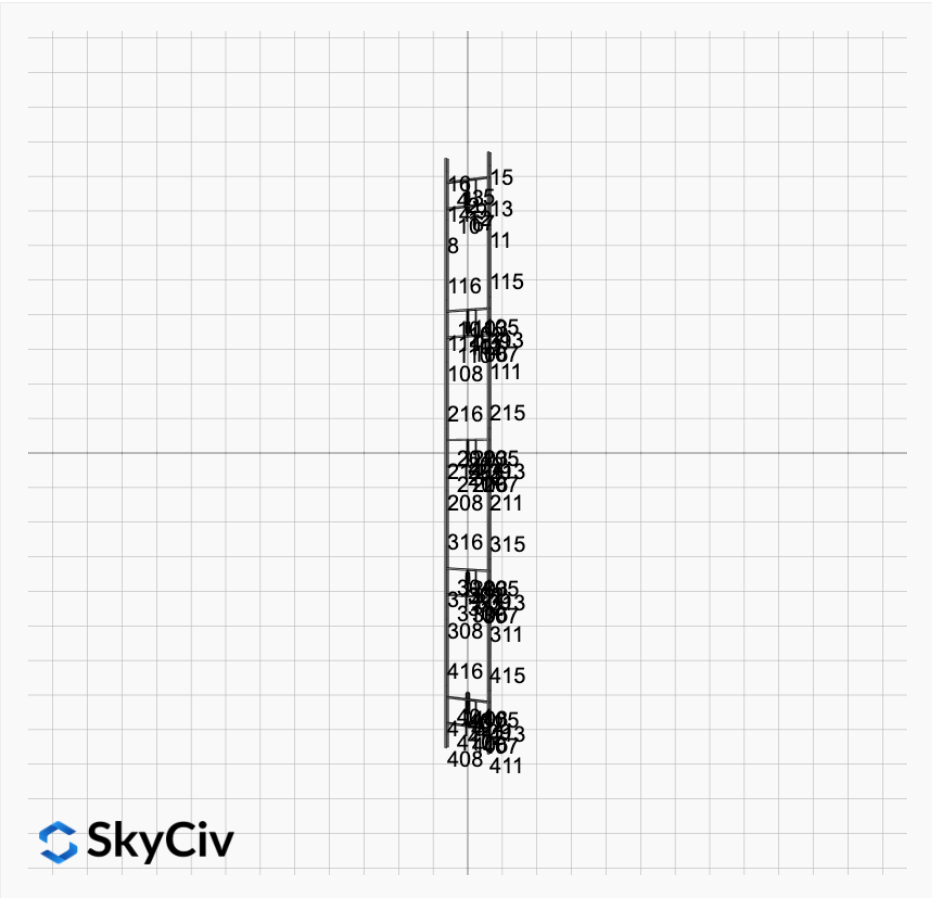
{"wind_speed_override":103,"snow_load_override":50,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"","designer_phone":"","project_id":"Elmira Corning Regional Airport - 590w - 4x12 -5P1975 - V1Jb","site_address":"276 Sing Sing Rd #1, Horseheads, NY 14845, USA","module_width":44.6,"module_length":89.7,"number_rows":"4","number_columns":12,"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":30,"ground_clearance":10,"risk_category":"I","exposure_category":"B","frame_duty_override":"HD","pole_override":"8_40","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":true}

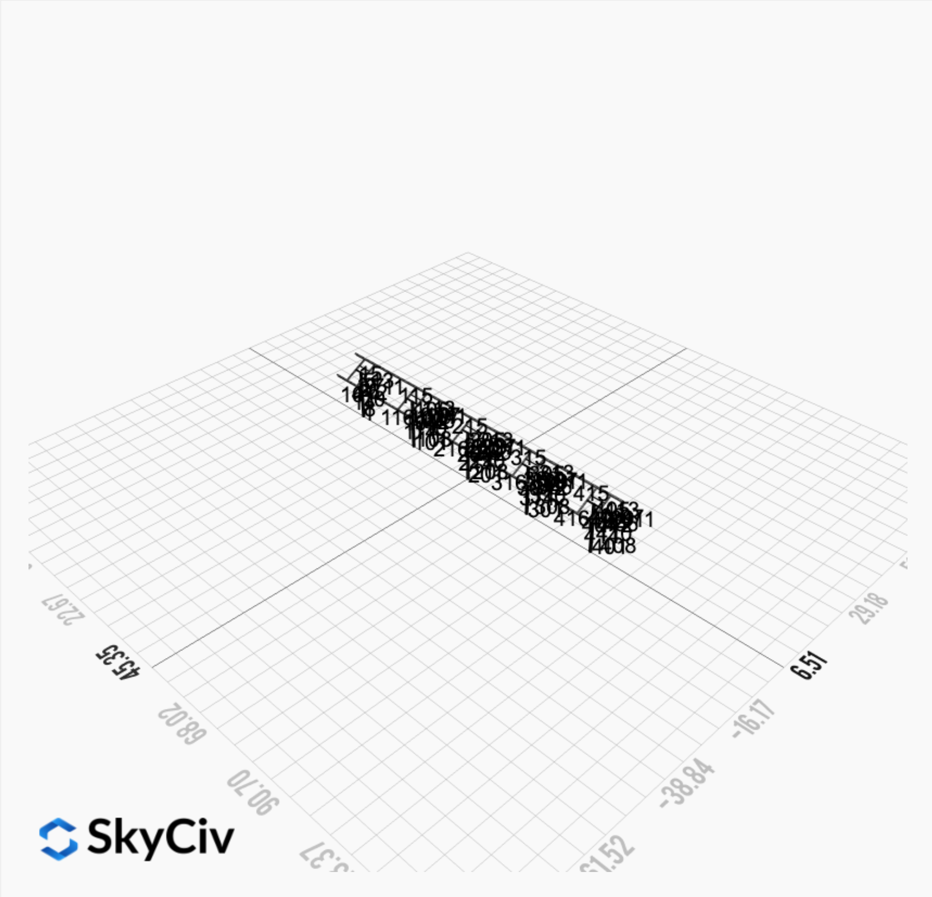
Design Notes:

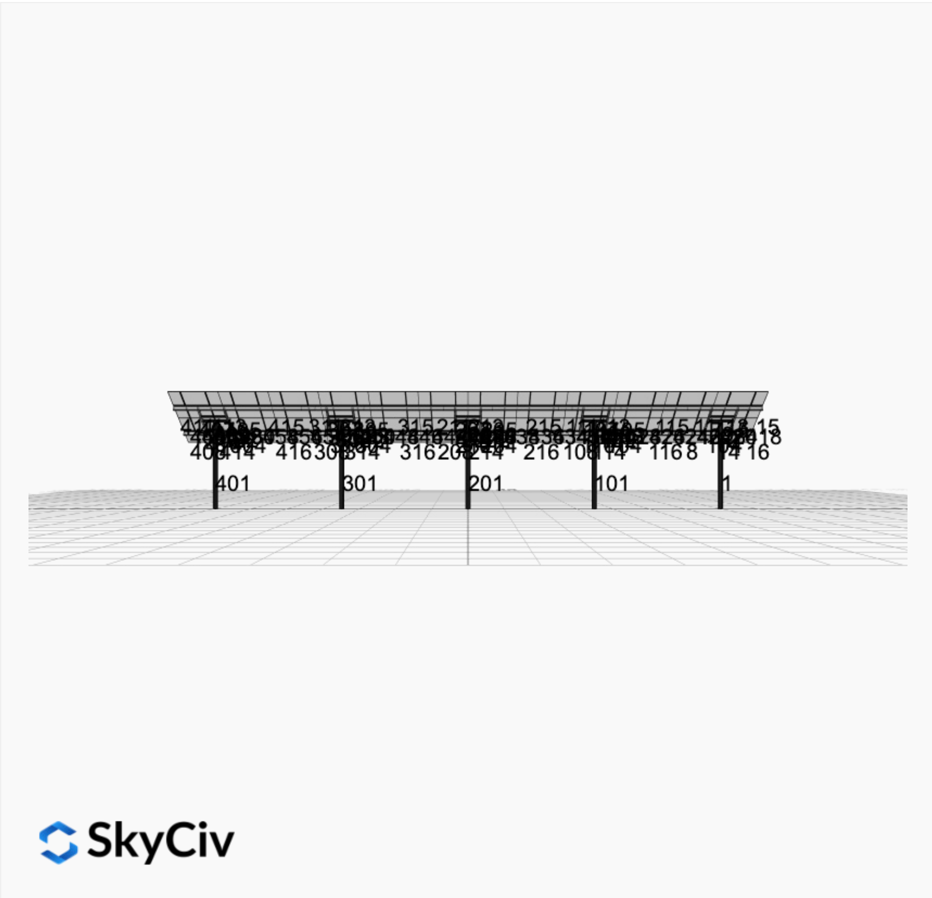
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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




401
6.51

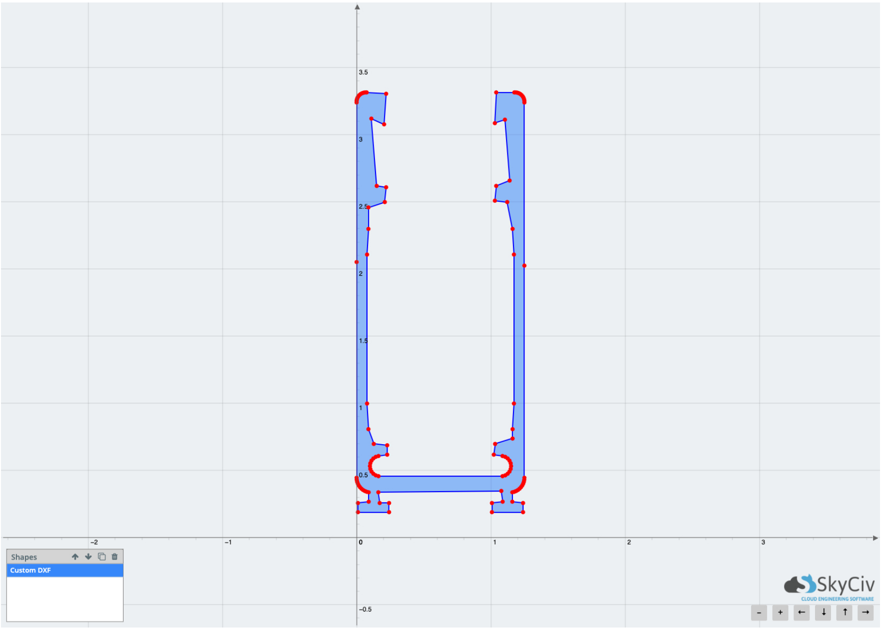

16
15
13
8
11
116
115
108
111
216
215
208
211
316
315
308
311
416
415
408
411


22.67
45.35
68.02
90.70
29.18
6.51
-16.17
-38.84
SkyCiv

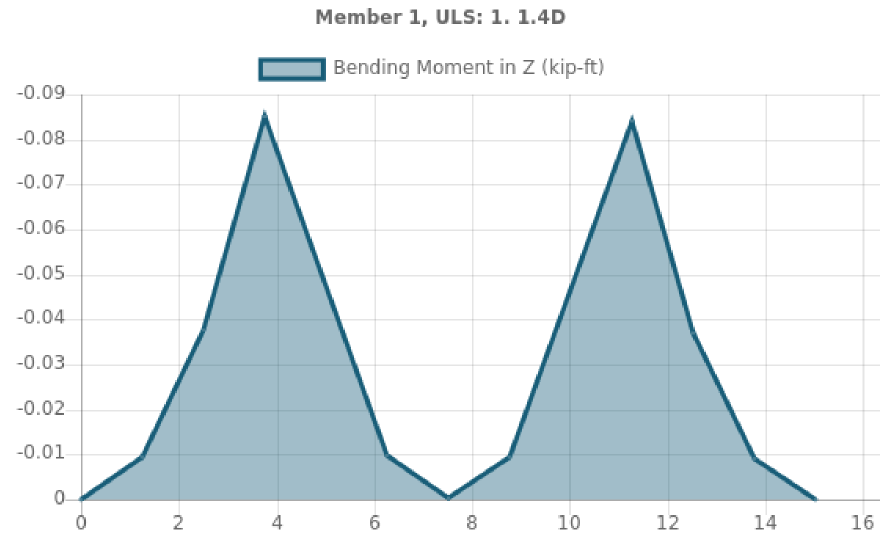

401
301
201
101
1
SkyCiv

Rail Design Check

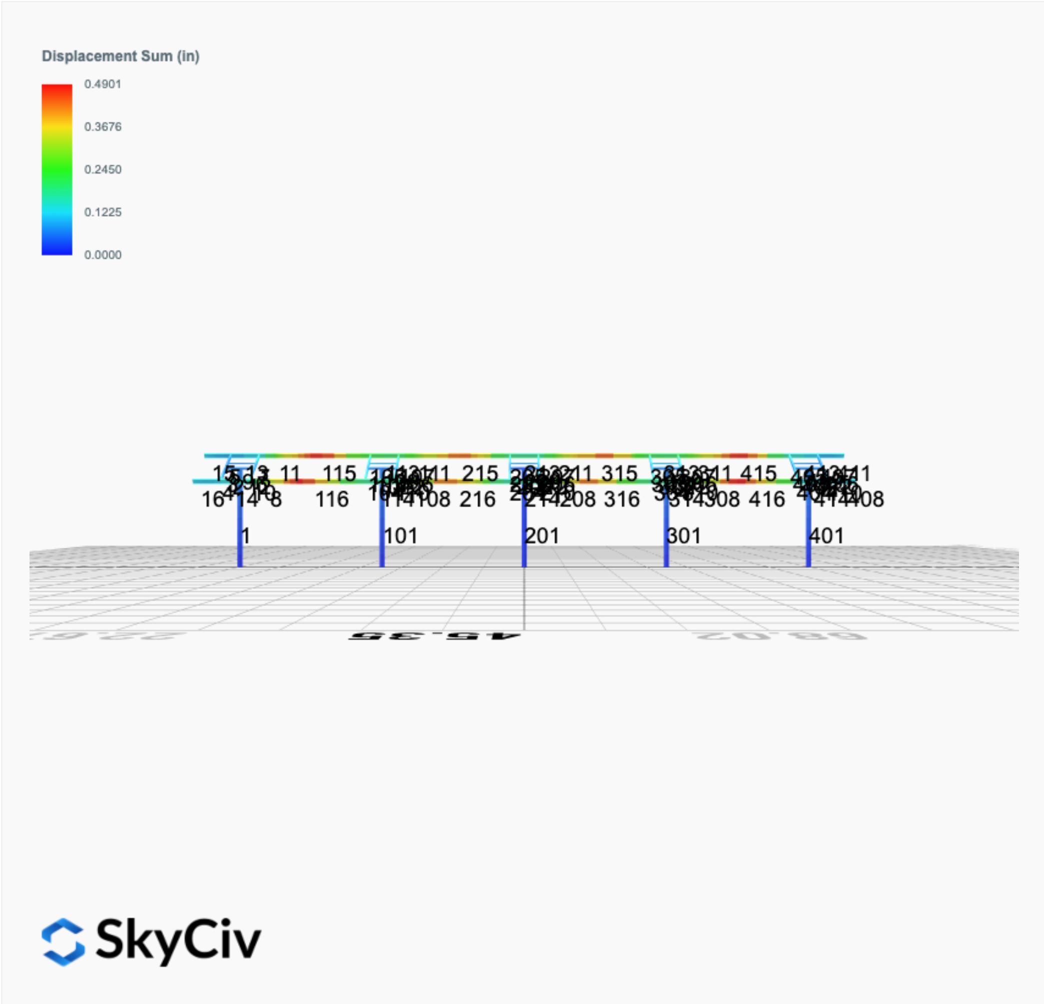
Rail Length: 15.033333333333333 ft
Additional Restraints Required: None
Tributary Width: 3.779166666666667 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0720 kip/ft
Snow (Y): -0.0416 kip/ft
Wind uplift Case A: 0.0741 kip/ft
Wind uplift Case A: 0.0741 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.1030 kip/ft

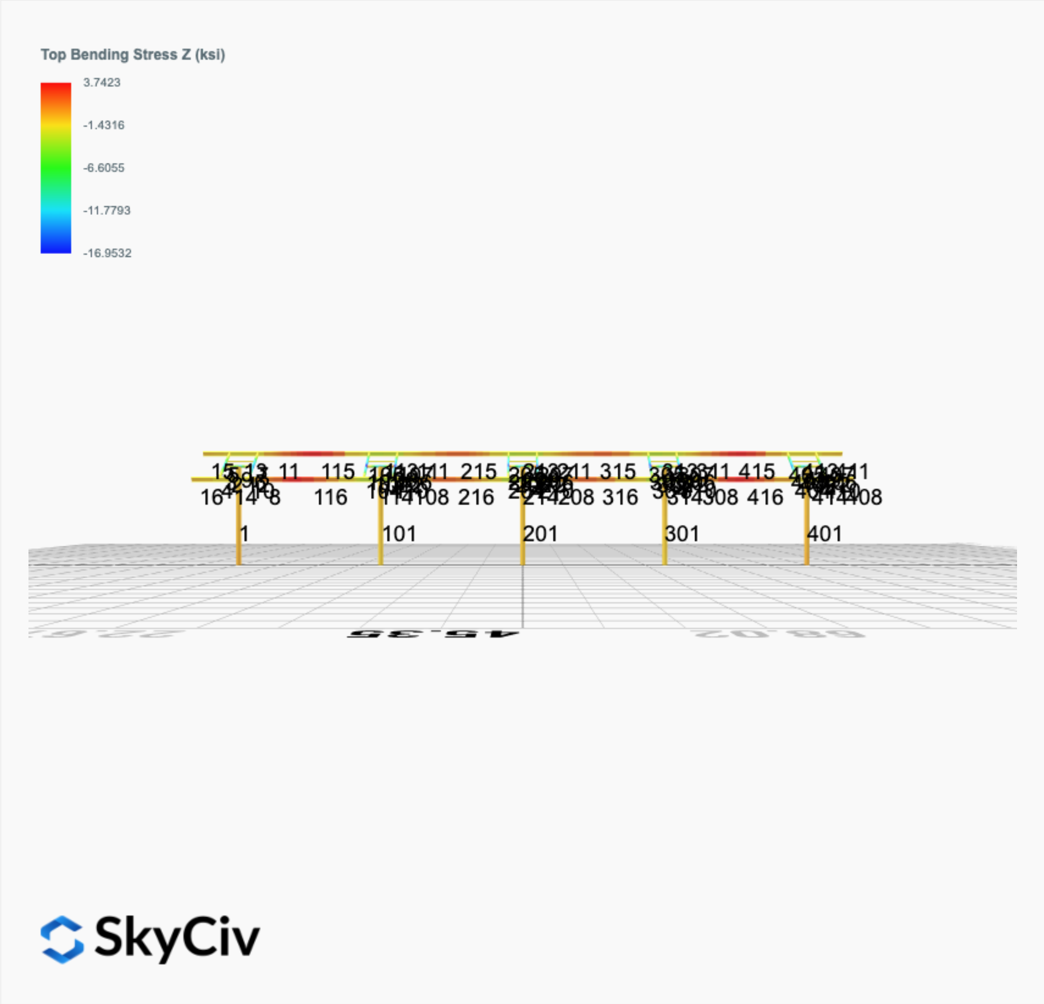


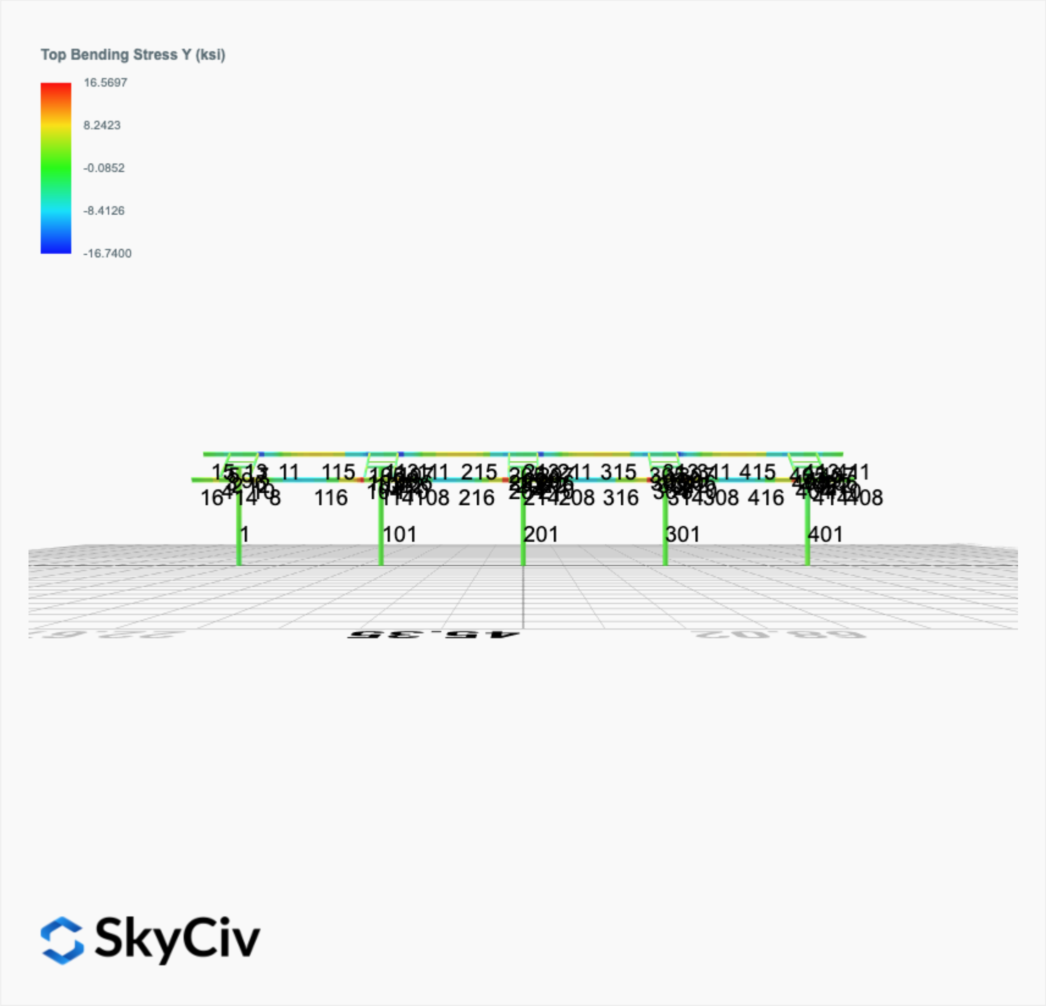
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	18.99305966	0.551	PASS
Material Yield	34.5	18.99305966	0.551	PASS
Material Strength	37	18.99305966	0.513	PASS

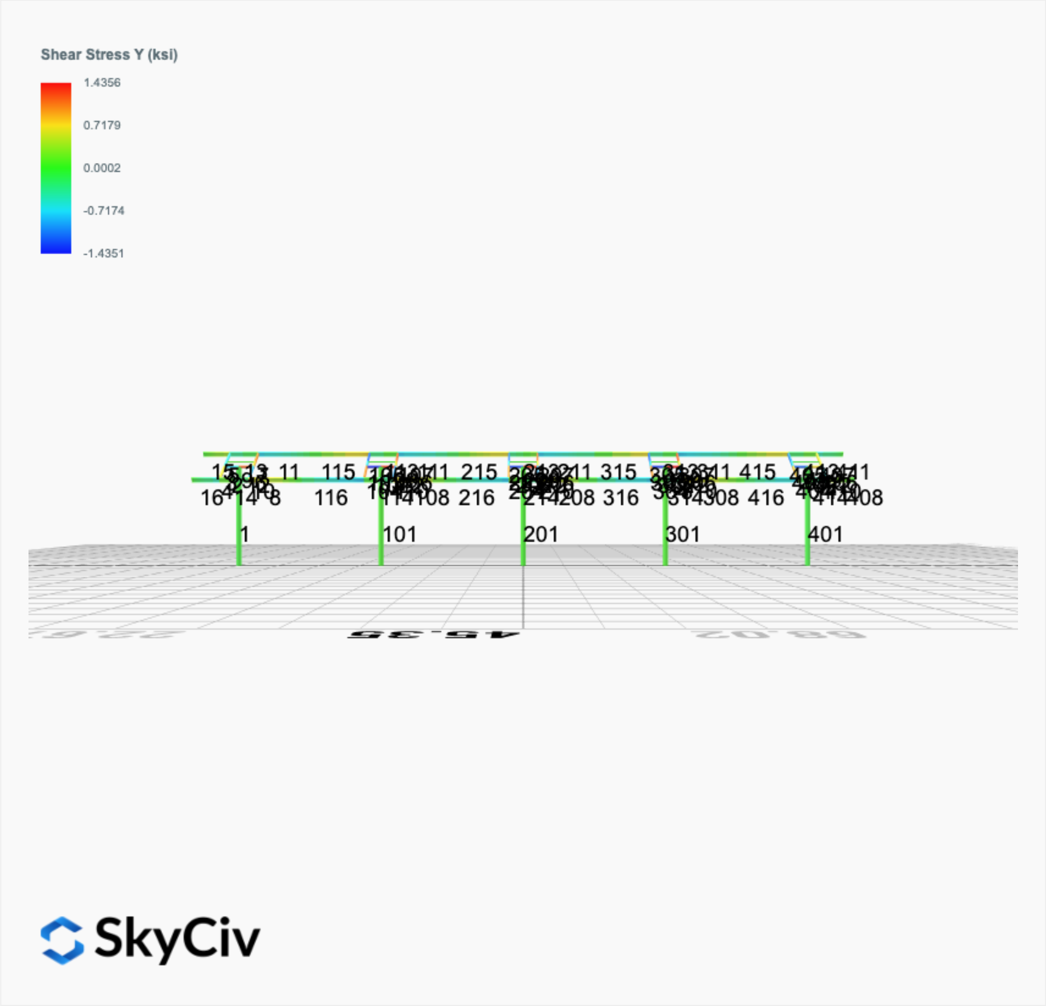


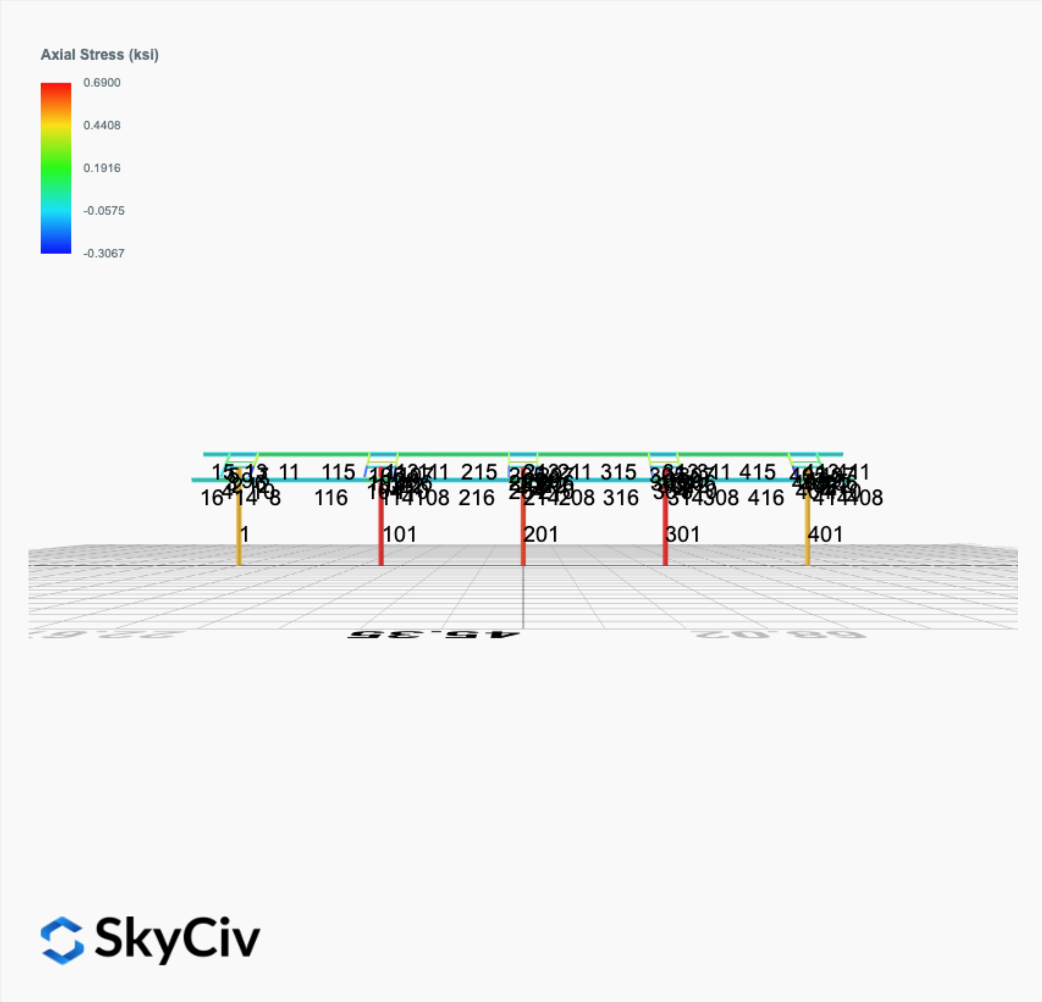
FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
3.7423
-1.4316
-6.6055
-11.7793
-16.9532
1
101
201
301
401
SkyCiv


Top Bending Stress Y (ksi)
16.5697
8.2423
-0.0852
-8.4126
-16.7400
1
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
1.4356
0.7179
0.0002
-0.7174
-1.4351
1
101
201
301
401
SkyCiv


Axial Stress (ksi)
0.6900
0.4408
0.1916
-0.0575
-0.3067
1
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	0.0199	1.9439	0.0604	0.2581	-0.0579	-0.2298
ULS: 2. D + L	0.0199	1.9439	0.0604	0.2581	-0.0579	-0.2298
ULS: 3. D + (S or Lr or R)	0.0840	6.2822	0.2573	1.1014	-0.2481	-1.0438
ULS: 3. D + (S or Lr or R)	0.0199	1.9439	0.0604	0.2581	-0.0579	-0.2298
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0680	5.1976	0.2081	0.8906	-0.2005	-0.8403
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0199	1.9439	0.0604	0.2581	-0.0579	-0.2298
ULS: 5b. D + 0.7E	0.0199	1.9439	0.0604	0.2581	-0.0579	-0.2298
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0680	5.1976	0.2081	0.8906	-0.2005	-0.8403
ULS: 8. 0.6D + 0.7E	0.0119	1.1664	0.0362	0.1549	-0.0348	-0.1379
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5946	4.6495	0.2404	1.0072	-0.5544	22.6210
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.5946	4.6495	0.2404	1.0072	-0.5544	22.6210
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.3993	-0.3727	-0.0896	-0.3647	0.3549	-19.0430
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.1922	0.0035	-0.0817	-0.3312	0.3434	-21.8439
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1429	7.2268	0.3431	1.4524	-0.5728	16.2978
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.1429	7.2268	0.3431	1.4524	-0.5728	16.2978
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1026	3.4601	0.0956	0.4235	0.1091	-14.9502
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.9472	3.7423	0.1015	0.4486	0.1005	-17.0509
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1910	3.9731	0.1954	0.8199	-0.4303	16.9083
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.1910	3.9731	0.1954	0.8199	-0.4303	16.9083
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0545	0.2064	-0.0521	-0.2090	0.2517	-14.3397
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8991	0.4886	-0.0462	-0.1839	0.2430	-16.4403
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.6025	3.8719	0.2162	0.9039	-0.5312	22.7129
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.6025	3.8719	0.2162	0.9039	-0.5312	22.7129
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.3914	-1.1503	-0.1138	-0.4679	0.3781	-18.9511
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.1842	-0.7741	-0.1059	-0.4345	0.3666	-21.7520

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.5306
Shear X	-2.6907
Shear Z	0.5434
Moment X	2.3150
Moment Y (Twist)	1.0053
Moment Z	38.2904

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.2268
Shear X	-1.6025
Shear Z	0.3431
Moment X	1.4524
Moment Y (Twist)	0.5728
Moment Z	22.7129

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	-0.0192	2.3936	-0.0055	-0.0243	0.0100	0.2606
ULS: 2. D + L	-0.0192	2.3936	-0.0055	-0.0243	0.0100	0.2606
ULS: 3. D + (S or Lr or R)	-0.0811	8.1891	-0.0232	-0.1029	0.0418	1.0628
ULS: 3. D + (S or Lr or R)	-0.0192	2.3936	-0.0055	-0.0243	0.0100	0.2606
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0656	6.7403	-0.0188	-0.0832	0.0339	0.8623

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0192	2.3936	-0.0055	-0.0243	0.0100	0.2606
ULS: 5b. D + 0.7E	-0.0192	2.3936	-0.0055	-0.0243	0.0100	0.2606
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0656	6.7403	-0.0188	-0.0832	0.0339	0.8623
ULS: 8. 0.6D + 0.7E	-0.0115	1.4362	-0.0033	-0.0146	0.0060	0.1564
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.0631	6.0174	0.0048	0.0134	-0.0641	28.9026
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.0631	6.0174	0.0048	0.0134	-0.0641	28.9026
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7370	-0.7159	-0.0118	-0.0462	0.0639	-23.2011
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4216	-0.1820	-0.0210	-0.0846	0.0968	-26.1949
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5986	9.4581	-0.0110	-0.0549	-0.0217	22.3438
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5986	9.4581	-0.0110	-0.0549	-0.0217	22.3438
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2516	4.4081	-0.0235	-0.0996	0.0743	-16.7340
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0150	4.8085	-0.0304	-0.1284	0.0990	-18.9794
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5521	5.1115	0.0023	0.0040	-0.0456	21.7421
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5521	5.1115	0.0023	0.0040	-0.0456	21.7421
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2980	0.0615	-0.0102	-0.0407	0.0504	-17.3356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0614	0.4619	-0.0171	-0.0695	0.0751	-19.5810
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0554	5.0599	0.0070	0.0232	-0.0681	28.7983
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0554	5.0599	0.0070	0.0232	-0.0681	28.7983
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7447	-1.6734	-0.0096	-0.0365	0.0599	-23.3053
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4293	-1.1395	-0.0188	-0.0749	0.0928	-26.2991

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	15.1608
Shear X	-3.4554
Shear Z	-0.0510
Moment X	-0.2182
Moment Y (Twist)	0.1823
Moment Z	49.7101

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.4581
Shear X	-2.0631
Shear Z	-0.0304
Moment X	-0.1284
Moment Y (Twist)	0.0990
Moment Z	28.9026

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	-0.0013	2.3472	-0.0000	-0.0004	-0.0006	0.0725
ULS: 2. D + L	-0.0013	2.3472	-0.0000	-0.0004	-0.0006	0.0725
ULS: 3. D + (S or Lr or R)	-0.0057	7.9928	-0.0001	-0.0018	-0.0025	0.2648
ULS: 3. D + (S or Lr or R)	-0.0013	2.3472	-0.0000	-0.0004	-0.0006	0.0725
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0046	6.5814	-0.0001	-0.0014	-0.0021	0.2167
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0013	2.3472	-0.0000	-0.0004	-0.0006	0.0725
ULS: 5b. D + 0.7E	-0.0013	2.3472	-0.0000	-0.0004	-0.0006	0.0725
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0046	6.5814	-0.0001	-0.0014	-0.0021	0.2167
ULS: 8. 0.6D + 0.7E	-0.0008	1.4083	-0.0000	-0.0002	-0.0004	0.0435
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.0458	5.9025	0.0000	-0.0007	-0.0013	29.0232
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.0458	5.9025	0.0000	-0.0007	-0.0013	29.0232
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7512	-0.6980	-0.0001	-0.0002	0.0000	-23.5848
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4590	-0.2020	-0.0001	-0.0002	0.0001	-26.8872

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5380	9.2479	-0.0001	-0.0016	-0.0026	21.9297
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5380	9.2479	-0.0001	-0.0016	-0.0026	21.9297
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3097	4.2975	-0.0001	-0.0013	-0.0016	-17.5263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0906	4.6695	-0.0001	-0.0013	-0.0016	-20.0031
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5347	5.0137	-0.0000	-0.0006	-0.0012	21.7856
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5347	5.0137	-0.0000	-0.0006	-0.0012	21.7856
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3131	0.0633	-0.0001	-0.0003	-0.0001	-17.6705
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0939	0.4353	-0.0001	-0.0003	-0.0001	-20.1473
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0453	4.9636	0.0000	-0.0005	-0.0011	28.9942
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0453	4.9636	0.0000	-0.0005	-0.0011	28.9942
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7517	-1.6369	-0.0001	-0.0000	0.0003	-23.6138
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4595	-1.1409	-0.0000	-0.0001	0.0003	-26.9162

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	14.8167
Shear X	-3.4116
Shear Z	-0.0002
Moment X	-0.0030
Moment Y (Twist)	0.0044
Moment Z	49.7692

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.2479
Shear X	-2.0458
Shear Z	-0.0001
Moment X	-0.0018
Moment Y (Twist)	0.0026
Moment Z	29.0232

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	-0.0192	2.3936	0.0055	0.0239	-0.0095	0.2611
ULS: 2. D + L	-0.0192	2.3936	0.0055	0.0239	-0.0095	0.2611
ULS: 3. D + (S or Lr or R)	-0.0813	8.1888	0.0234	0.1013	-0.0400	1.0649
ULS: 3. D + (S or Lr or R)	-0.0192	2.3936	0.0055	0.0239	-0.0095	0.2611
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0658	6.7400	0.0189	0.0819	-0.0324	0.8639
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0192	2.3936	0.0055	0.0239	-0.0095	0.2611
ULS: 5b. D + 0.7E	-0.0192	2.3936	0.0055	0.0239	-0.0095	0.2611
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0658	6.7400	0.0189	0.0819	-0.0324	0.8639
ULS: 8. 0.6D + 0.7E	-0.0115	1.4361	0.0033	0.0144	-0.0057	0.1567
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.0630	6.0171	-0.0048	-0.0144	0.0632	28.9011
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.0630	6.0171	-0.0048	-0.0144	0.0632	28.9011
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7369	-0.7158	0.0118	0.0464	-0.0624	-23.1991
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4214	-0.1819	0.0210	0.0846	-0.0951	-26.1938
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5986	9.4577	0.0112	0.0532	0.0222	22.3440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5986	9.4577	0.0112	0.0532	0.0222	22.3440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2513	4.4080	0.0236	0.0988	-0.0720	-16.7312
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0147	4.8084	0.0305	0.1274	-0.0965	-18.9772
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5521	5.1112	-0.0022	-0.0048	0.0450	21.7411
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5521	5.1112	-0.0022	-0.0048	0.0450	21.7411
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2979	0.0615	0.0102	0.0408	-0.0492	-17.3341
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0613	0.4619	0.0172	0.0694	-0.0737	-19.5801

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0553	5.0597	-0.0070	-0.0240	0.0670	28.7967
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0553	5.0597	-0.0070	-0.0240	0.0670	28.7967
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7446	-1.6733	0.0096	0.0368	-0.0586	-23.3035
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4291	-1.1394	0.0188	0.0750	-0.0913	-26.2982

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	15.1602
Shear X	-3.4553
Shear Z	0.0513
Moment X	0.2164
Moment Y (Twist)	0.1789
Moment Z	49.7081

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.4577
Shear X	-2.0630
Shear Z	0.0305
Moment X	0.1274
Moment Y (Twist)	0.0965
Moment Z	28.9011

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	0.0199	1.9439	-0.0604	-0.2587	0.0584	-0.2299
ULS: 2. D + L	0.0199	1.9439	-0.0604	-0.2587	0.0584	-0.2299
ULS: 3. D + (S or Lr or R)	0.0841	6.2822	-0.2574	-1.1041	0.2501	-1.0443
ULS: 3. D + (S or Lr or R)	0.0199	1.9439	-0.0604	-0.2587	0.0584	-0.2299
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0680	5.1976	-0.2082	-0.8928	0.2022	-0.8407
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0199	1.9439	-0.0604	-0.2587	0.0584	-0.2299
ULS: 5b. D + 0.7E	0.0199	1.9439	-0.0604	-0.2587	0.0584	-0.2299
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0680	5.1976	-0.2082	-0.8928	0.2022	-0.8407
ULS: 8. 0.6D + 0.7E	0.0119	1.1664	-0.0362	-0.1552	0.0351	-0.1379
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5946	4.6495	-0.2405	-1.0090	0.5544	22.6208
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.5946	4.6495	-0.2405	-1.0090	0.5544	22.6208
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.3993	-0.3728	0.0897	0.3651	-0.3540	-19.0431
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.1922	0.0035	0.0818	0.3314	-0.3425	-21.8452
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1428	7.2268	-0.3432	-1.4555	0.5741	16.2973
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.1428	7.2268	-0.3432	-1.4555	0.5741	16.2973
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1026	3.4601	-0.0956	-0.4250	-0.1072	-14.9507
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.9473	3.7423	-0.1015	-0.4502	-0.0986	-17.0522
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1909	3.9731	-0.1955	-0.8214	0.4304	16.9082
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.1909	3.9731	-0.1955	-0.8214	0.4304	16.9082
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0545	0.2064	0.0522	0.2091	-0.2509	-14.3398
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8991	0.4886	0.0462	0.1839	-0.2423	-16.4414
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.6025	3.8719	-0.2163	-0.9055	0.5310	22.7128
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.6025	3.8719	-0.2163	-0.9055	0.5310	22.7128
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.3914	-1.1503	0.1139	0.4685	-0.3774	-18.9512
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.1843	-0.7741	0.1059	0.4349	-0.3659	-21.7533

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	11.5306
Shear X	-2.6907
Shear Z	-0.5435
Moment X	-2.3201
Moment Y (Twist)	1.0059
Moment Z	38.2904

Result	Value (kip, kip-ft)
Axial	7.2268
Shear X	-1.6025
Shear Z	-0.3432
Moment X	-1.4555
Moment Y (Twist)	0.5741
Moment Z	22.7128

Project Details

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

Design Input Information

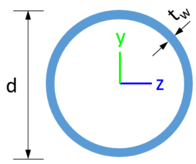
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

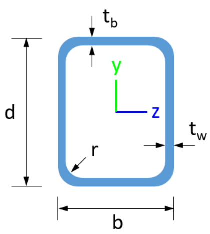
Design Materials

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

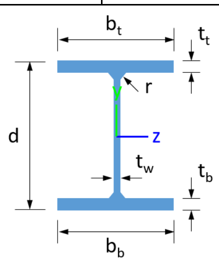
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
9	8in Pipe Sch 40	8.63	0.32					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	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)

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	28.89	28.89	13.76	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.19,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.13,1.15,1.17,1.17,1.16,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.73,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.70,1.67,1.67,1.66,1.80	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	1.31,1.31,1.31,1.31,1.31,1.31,1.31,1.31,1.30,1.43,1.31,1.31,1.31,1.32,1.31,1.31,1.32,1.33,1.31,1.31,1.30,1.47,1.31,1.31,1.31,1.03	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.15,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.61	300	200	1
11	19	1.33	1.33	2.05	1.34,1.34,1.34,1.34,1.34,1.34,1.39,1.39,1.77,1.64,1.40,1.40,1.45,1.49,1.36,1.36,1.31,1.28,1.39,1.39,1.60,1.58,1.41,1.41,1.44,1.47	300	200	1
12	5	4.20	4.20	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.15,1.15,1.26,1.36,1.14,1.14,1.12,1.22,1.17,1.17,1.22,1.20,1.15,1.15,1.21,1.32,1.14,1.14,1.12,1.21	300	200	1
14	19	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.17,1.17,1.11,1.45,1.17,1.17,1.16,1.79,1.18,1.18,1.20,1.22,1.17,1.17,1.13,1.53,1.17,1.17,1.16,1.74	300	200	1
15	19	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	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	28.89	28.89	13.76	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
104	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	19	1.33	1.33	2.05	2.11,2.11,2.11,2.11,2.11,2.11,2.10,2.10,2.07,2.11,2.10,2.10,2.09,2.06,2.11,2.11,2.12,2.11,2.10,2.10,2.08,2.11,2.10,2.10,2.09,2.38	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.92,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.59	300	200	1
111	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.06,2.06,1.44,1.61,2.02,2.02,1.82,1.83,2.07,2.07,2.11,2.34,2.06,2.06,1.57,1.68,2.00,2.00,1.87,1.86	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.08,1.26,1.31,1.08,1.08,1.10,1.13,1.07,1.07,1.05,1.04,1.08,1.08,1.16,1.24,1.08,1.08,1.09,1.12	300	200	1
114	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.11,1.15,1.06,1.06,1.07,1.12,1.06,1.06,1.05,1.05,1.06,1.06,1.09,1.21,1.06,1.06,1.07,1.08	300	200	1
115	19	10.20	10.20	10.20	1.16,1.16,1.16,1.15,1.16,1.16,1.13,1.13,1.08,1.09,1.13,1.13,1.11,1.11,1.14,1.14,1.17,1.19,1.13,1.13,1.08,1.09,1.12,1.12,1.11,1.11	300	200	1
116	19	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.34,1.17,1.17,1.17,1.17,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.42	300	200	1
201	9	28.89	28.89	13.76	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.82,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.56	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.09,2.10,2.10,2.09,2.09,2.09,1.89,2.09,2.09,2.08,2.09,2.09,2.09,2.10,2.10,2.09,2.09,2.09,1.51	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.82,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.56	300	200	1
211	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.08,2.08,1.65,1.98,2.07,2.07,2.06,2.07,2.09,2.09,2.12,2.24,2.08,2.08,1.81,2.06,2.07,2.07,2.06,2.07	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.08,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.07,1.04,1.04,1.04,1.05	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.04,1.04,1.04,1.18,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.17,1.04,1.04,1.04,1.02	300	200	1
215	19	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.13,1.14,1.15,1.15,1.14,1.15,1.16,1.16,1.17,1.18,1.15,1.15,1.13,1.15,1.15,1.15,1.14,1.15	300	200	1
216	19	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.31,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.13	300	200	1
301	9	28.89	28.89	13.76	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.92,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.59	300	200	1
305	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
308	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.03,2.03,1.77,1.93,2.01,2.01,1.96,1.10,2.07,2.07,2.07,2.07,2.03,2.03,1.85,1.87,2.01,2.01,1.97,2.21	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.57	300	200	1
311	19	1.33	1.33	2.05	1.90,1.90,1.90,1.89,1.90,1.90,1.63,1.63,1.23,1.34,1.59,1.59,1.48,1.47,1.76,1.76,2.08,2.10,1.64,1.64,1.32,1.38,1.58,1.58,1.50,1.49	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.08,1.26,1.31,1.08,1.08,1.10,1.13,1.07,1.07,1.05,1.04,1.08,1.08,1.16,1.24,1.08,1.08,1.09,1.12	300	200	1
314	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.10,1.15,1.06,1.06,1.07,1.12,1.06,1.06,1.05,1.05,1.06,1.06,1.09,1.21,1.06,1.06,1.07,1.08	300	200	1

315	19	10.20	10.20	10.20	1.21,1.21,1.21,1.21,1.21,1.21,1.19,1.19,1.14,1.16,1.19,1.19,1.18,1.18,1.20,1.20,1.23,1.24,1.19,1.19,1.16,1.17,1.19,1.19,1.18,1.18	300	200	1
316	19	10.20	10.20	10.20	1.22,1.22,1.22,1.22,1.22,1.22,1.22,1.20,1.22,1.22,1.22,1.21,1.22,1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.22,1.22,1.22,1.21,1.23	300	200	1
401	9	28.89	28.89	13.76	-	300	200	1
402	5	4.20	4.20	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.15,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.61	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
406	16	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.19,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.13,1.15,1.17,1.17,1.16,1.17	300	200	1
407	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
408	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.73,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.70,1.67,1.67,1.66,1.80	300	200	1
411	19	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	5	1.30	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.15,1.15,1.26,1.36,1.14,1.14,1.12,1.22,1.17,1.17,1.22,1.20,1.15,1.15,1.21,1.32,1.14,1.14,1.12,1.21	300	200	1
414	19	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.17,1.17,1.11,1.45,1.17,1.17,1.16,1.80,1.18,1.18,1.20,1.22,1.17,1.17,1.14,1.53,1.17,1.17,1.16,1.74	300	200	1
415	19	10.20	10.20	10.20	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.16,1.14,1.10,1.10,1.11,1.11,1.10,1.10,1.10,1.09,1.10,1.10,1.13,1.13,1.10,1.10,1.11,1.11	300	200	1
416	19	10.20	10.20	10.20	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.11,1.10,1.10,1.10,2.37,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.11,1.10,1.10,1.10,1.14	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	136.23	83.29	83.29	113.39	113.39
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	182.14	21.95	21.95	59.50	59.50
13	133.20	85.85	25.60	6.12	40.24	43.62
14	133.20	85.85	25.42	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	377.97	136.23	83.29	83.29	113.39	113.39
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28

104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.80	6.12	40.24	43.62
114	133.20	85.85	23.98	6.12	40.24	43.62
115	133.20	31.52	16.72	6.12	40.24	43.62
116	133.20	31.52	17.73	6.12	40.24	43.62
201	377.97	136.23	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.79	6.12	40.24	43.62
214	133.20	85.85	23.32	6.12	40.24	43.62
215	133.20	31.52	17.45	6.12	40.24	43.62
216	133.20	31.52	17.42	6.12	40.24	43.62
301	377.97	136.23	83.29	83.29	113.39	113.39
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	123.95	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	123.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	23.80	6.12	40.24	43.62
314	133.20	85.85	23.98	6.12	40.24	43.62
315	133.20	31.52	17.64	6.12	40.24	43.62
316	133.20	31.52	18.59	6.12	40.24	43.62
401	377.97	136.23	83.29	83.29	113.39	113.39
402	198.33	182.14	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28

407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	102.39	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	102.39	32.87	6.12	40.24	43.62
412	198.33	196.72	21.95	21.95	59.50	59.50
413	133.20	85.85	25.60	6.12	40.24	43.62
414	133.20	85.85	25.45	6.12	40.24	43.62
415	133.20	31.52	16.92	6.12	40.24	43.62
416	133.20	31.52	16.91	6.12	40.24	43.62

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	0.085	0.460	0.062	0.024	0.005	0.517	#13	0.590	Not Required	Pass
2	0.003	0.296	0.102	0.073	0.020	0.374	#21	0.035	Not Required	Pass
3	0.007	0.495	0.028	0.048	0.003	0.518	#21	0.045	Not Required	Pass
4	0.006	0.493	0.087	0.050	0.022	0.580	#21	0.080	Not Required	Pass
5	0.007	0.308	0.063	0.049	0.016	0.320	#21	0.074	Not Required	Pass
6	0.012	0.717	0.117	0.074	0.031	0.840	#21	0.045	Not Required	Pass
7	0.013	0.445	0.203	0.071	0.050	0.491	#21	0.074	Not Required	Pass
8	0.004	0.139	0.181	0.045	0.020	0.229	#21	0.095	Not Required	Pass
9	0.008	0.071	0.091	0.003	0.005	0.159	#21	0.204	Not Required	Pass
10	0.014	0.692	0.184	0.070	0.039	0.788	#21	0.080	Not Required	Pass
11	0.006	0.132	0.188	0.047	0.020	0.220	#21	0.095	Not Required	Pass
12	0.001	0.531	0.148	0.113	0.026	0.644	#21	0.171	Not Required	Pass
13	0.009	0.122	0.474	0.061	0.026	0.526	#21	0.286	Not Required	Pass
14	0.006	0.114	0.465	0.059	0.026	0.522	#24	0.190	Not Required	Pass
15	0.000	0.020	0.046	0.016	0.006	0.066	#21	Not Required	Not Required	Pass
16	0.000	0.020	0.046	0.016	0.006	0.066	#21	Not Required	Not Required	Pass
101	0.111	0.597	0.006	0.030	0.000	0.640	#13	0.590	Not Required	Pass
102	0.004	0.559	0.167	0.125	0.028	0.699	#21	0.035	Not Required	Pass
103	0.013	0.804	0.077	0.080	0.011	0.887	#21	0.045	Not Required	Pass
104	0.013	0.817	0.208	0.082	0.044	0.960	#21	0.080	Not Required	Warn
105	0.013	0.499	0.218	0.080	0.055	0.556	#21	0.074	Not Required	Pass
106	0.012	0.802	0.075	0.080	0.011	0.876	#21	0.045	Not Required	Pass
107	0.012	0.498	0.203	0.080	0.052	0.553	#21	0.074	Not Required	Pass
108	0.005	0.057	0.179	0.051	0.020	0.226	#21	0.095	Not Required	Pass
109	0.017	0.068	0.056	0.001	0.000	0.130	#21	0.204	Not Required	Pass
110	0.012	0.801	0.197	0.080	0.042	0.938	#21	0.080	Not Required	Pass
111	0.007	0.067	0.186	0.050	0.020	0.222	#21	0.095	Not Required	Pass
112	0.004	0.550	0.172	0.122	0.031	0.690	#21	0.035	Not Required	Pass
113	0.009	0.236	0.505	0.068	0.026	0.707	#21	0.286	Not Required	Pass
114	0.010	0.265	0.500	0.070	0.026	0.730	#21	0.286	Not Required	Pass
115	0.025	0.370	0.256	0.054	0.020	0.637	#21	0.728	Not Required	Pass
116	0.009	0.359	0.257	0.056	0.021	0.616	#21	0.728	Not Required	Pass
201	0.109	0.598	0.000	0.030	0.000	0.640	#13	0.590	Not Required	Pass
202	0.003	0.543	0.167	0.121	0.029	0.678	#21	0.035	Not Required	Pass
203	0.012	0.792	0.075	0.079	0.011	0.873	#21	0.045	Not Required	Pass
204	0.012	0.778	0.190	0.078	0.040	0.912	#21	0.080	Not Required	Pass
205	0.012	0.492	0.198	0.078	0.050	0.545	#21	0.074	Not Required	Pass

206	0.012	0.792	0.075	0.079	0.011	0.873	#21	0.045	Not Required	Pass
207	0.012	0.492	0.199	0.079	0.050	0.545	#21	0.074	Not Required	Pass
208	0.005	0.061	0.171	0.050	0.020	0.215	#21	0.095	Not Required	Pass
209	0.015	0.067	0.053	0.001	0.000	0.127	#21	0.204	Not Required	Pass
210	0.012	0.778	0.190	0.078	0.040	0.912	#21	0.080	Not Required	Pass
211	0.007	0.062	0.176	0.051	0.020	0.223	#21	0.095	Not Required	Pass
212	0.003	0.543	0.167	0.121	0.029	0.678	#21	0.035	Not Required	Pass
213	0.010	0.253	0.459	0.065	0.025	0.695	#21	0.286	Not Required	Pass
214	0.009	0.255	0.453	0.064	0.025	0.681	#21	0.286	Not Required	Pass
215	0.026	0.266	0.254	0.051	0.020	0.529	#21	0.728	Not Required	Pass
216	0.013	0.257	0.252	0.050	0.020	0.509	#21	0.728	Not Required	Pass
301	0.111	0.597	0.006	0.030	0.000	0.640	#13	0.590	Not Required	Pass
302	0.004	0.550	0.172	0.122	0.031	0.690	#21	0.035	Not Required	Pass
303	0.012	0.802	0.075	0.080	0.011	0.876	#21	0.045	Not Required	Pass
304	0.012	0.801	0.197	0.080	0.042	0.938	#21	0.080	Not Required	Pass
305	0.012	0.499	0.203	0.079	0.052	0.554	#21	0.074	Not Required	Pass
306	0.013	0.804	0.077	0.080	0.011	0.887	#21	0.045	Not Required	Pass
307	0.013	0.499	0.218	0.080	0.055	0.556	#21	0.074	Not Required	Pass
308	0.004	0.085	0.208	0.056	0.021	0.243	#21	0.095	Not Required	Pass
309	0.017	0.068	0.056	0.001	0.000	0.130	#21	0.204	Not Required	Pass
310	0.013	0.817	0.208	0.082	0.044	0.960	#21	0.080	Not Required	Warn
311	0.006	0.097	0.212	0.054	0.021	0.232	#21	0.095	Not Required	Pass
312	0.004	0.560	0.167	0.125	0.028	0.699	#21	0.035	Not Required	Pass
313	0.010	0.236	0.505	0.068	0.026	0.707	#21	0.286	Not Required	Pass
314	0.010	0.265	0.500	0.070	0.026	0.730	#21	0.286	Not Required	Pass
315	0.026	0.261	0.258	0.050	0.020	0.529	#21	0.728	Not Required	Pass
316	0.013	0.248	0.257	0.051	0.020	0.505	#21	0.728	Not Required	Pass
401	0.085	0.460	0.062	0.024	0.005	0.517	#13	0.590	Not Required	Pass
402	0.001	0.530	0.148	0.113	0.026	0.644	#21	0.171	Not Required	Pass
403	0.012	0.718	0.117	0.074	0.031	0.841	#21	0.045	Not Required	Pass
404	0.014	0.692	0.185	0.070	0.039	0.788	#21	0.080	Not Required	Pass
405	0.013	0.445	0.203	0.071	0.050	0.492	#21	0.074	Not Required	Pass
406	0.007	0.495	0.028	0.048	0.003	0.518	#21	0.045	Not Required	Pass
407	0.007	0.308	0.063	0.049	0.016	0.320	#21	0.074	Not Required	Pass
408	0.000	0.020	0.046	0.016	0.006	0.066	#21	Not Required	Not Required	Pass
409	0.008	0.071	0.091	0.003	0.005	0.159	#21	0.204	Not Required	Pass
410	0.006	0.493	0.087	0.050	0.022	0.580	#21	0.080	Not Required	Pass
411	0.000	0.020	0.046	0.016	0.006	0.066	#21	Not Required	Not Required	Pass
412	0.003	0.296	0.102	0.073	0.020	0.374	#21	0.035	Not Required	Pass
413	0.009	0.122	0.474	0.061	0.026	0.526	#21	0.190	Not Required	Pass
414	0.006	0.114	0.465	0.059	0.026	0.522	#24	0.286	Not Required	Pass
415	0.025	0.384	0.256	0.047	0.020	0.652	#21	0.728	Not Required	Pass
416	0.009	0.382	0.257	0.045	0.020	0.639	#21	0.728	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/comresssion)
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

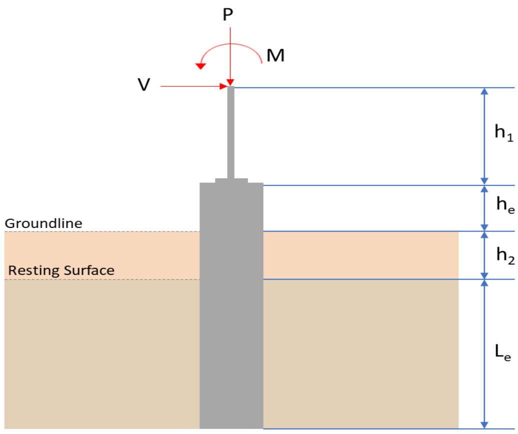
SkyCiv Foundation Design

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
$L = 6.25\ \text{ft}$ - 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)	7.227	11.531
V_x (kip)	-1.603	-2.691
V_z (kip)	0.343	0.543
M_x (kipft)	1.452	2.315
M_z (kipft)	22.713	38.290

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.603\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.25525\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.713\ \text{kipft}) + ((-1.603\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.6167\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.8461\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.343\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.054618\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.452\ \text{kipft}) + ((0.343\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.23121\ \text{kipft/ft}$$

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:
$L_{e,z} = 3.0548\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8461\ \text{ft}), (3.0548\ \text{ft})]$$

$$L_{e,req} = 5.846\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.846\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.93536$$

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

	$$q = \frac{P_v}{A}$$ $$q = \frac{(7.227\ \text{kip})}{(16\ \text{ft}^2)}$$ $$q = 0.45169\ \text{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.45169\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$ $$Ratio = 0.22584$$	Status: **PASS** Ratio: **0.230**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(6.25\ \text{ft})}{(48\ \text{in})}$$ $$L/D = 1.5625$$ Since L/D $\leq$ 10, Pile is short. **Considering x-direction:** $H_o = -0.25525\ \text{kip/ft}$ - Lateral force per length of pile, $M_o = 3.6167\ \text{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (3.6167\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.25525\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (3.6167\ \text{kipft/ft})) + (4 \times (-0.25525\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$ $$a = 4.285\ \text{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (3.6167\ \text{kipft/ft})) + (3 \times (-0.25525\ \text{kip/ft}) \times (6.25\ \text{ft}))]^{\,2}}{(6.25\ \text{ft})^2 \times [(3 \times (3.6167\ \text{kipft/ft})) + (2 \times (-0.25525\ \text{kip/ft}) \times (6.25\ \text{ft}))]}$$ $$p = 0.23493\ \text{kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (3.6167\ \text{kipft/ft})) + ((-0.25525\ \text{kip/ft}) \times (6.25\ \text{ft}))]}{(6.25\ \text{ft})^2}$$ $$s = 0.86601\ \text{kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \text{psf/ft}) \times \frac{(4.285\ \text{ft})}{2}$$ $$p_a = 0.32138\ \text{kip/ft}^2$$ $Ratio$ - Lateral soil capacity	

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.23493 \text{ kip/ft}^2\right)}{\left(0.32138 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.731$$	Status: **PASS** Ratio: **0.730**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150 \text{ psf/ft}) \times (6.25 \text{ ft})$$ $$p_s = 0.9375 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.86601 \text{ kip/ft}^2\right)}{\left(0.9375 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.92375$$	Status: **PASS** Ratio: **0.920**
	Considering z-direction: $H_o = 0.054618 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.23121 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.23121 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (0.054618 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (0.23121 \text{ kipft/ft})) + (4 \times (0.054618 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$ $$a = 4.425 \text{ ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.23121 \text{ kipft/ft})) + (3 \times (0.054618 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 \times [(3 \times (0.23121 \text{ kipft/ft})) + (2 \times (0.054618 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$ $$p = 0.052986 \text{ kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.23121 \text{ kipft/ft})) + ((0.054618 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$ $$s = 0.12346 \text{ kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150 \text{ psf/ft}) \times \frac{(4.425 \text{ ft})}{2}$$ $$p_a = 0.33188 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.052986 \text{ kip/ft}^2\right)}{\left(0.33188 \text{ kip/ft}^2\right)}$$	

$$Ratio = 0.15966$$

Status: **PASS**
Ratio: **0.160**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.25\ \text{ft})$$

$$p_s = 0.9375\ \text{kip/ft}^2$$

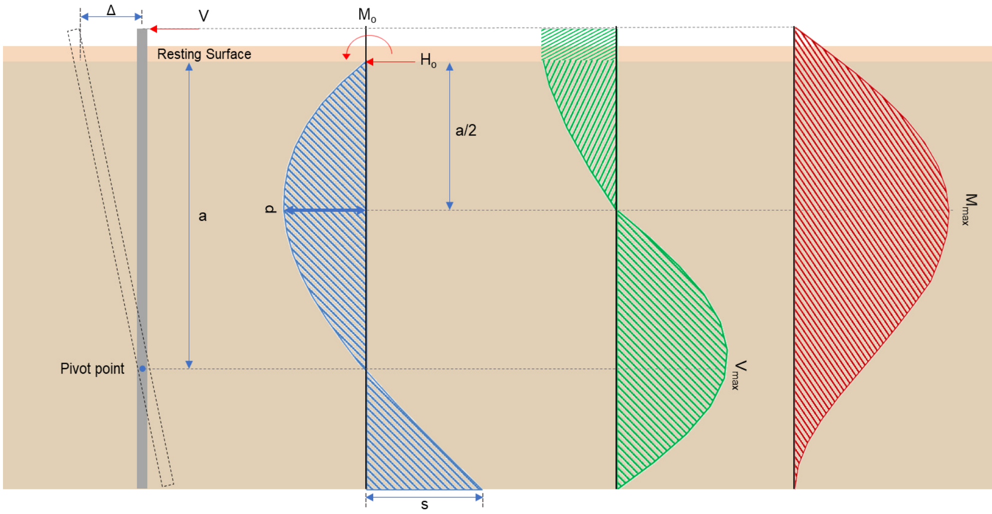
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.12346\ \text{kip/ft}^2)}{(0.9375\ \text{kip/ft}^2)}$$

$$Ratio = 0.13169$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.691\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.4285\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.29\ \text{kipft}) + ((-2.691\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.0971\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.0971\ \text{kipft/ft})}{(-0.4285\ \text{kip/ft})}$$

$$E = 14.229\ \text{ft}$$

a - Distance from resisting surface to pivot point,

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

$$a = \frac{(4 \times (6.0971\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.4285\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (6.0971\ \mathrm{kipft/ft})) + (4 \times (-0.4285\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2846\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.4285\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.229\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2846\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.229\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2846\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.0381\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.4285\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.25\ \mathrm{ft})) \times \left[\left(\frac{(14.229\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + \frac{(4.2846\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.229\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2846\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.229\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2846\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 24.143\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.543\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.086465\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.315\ \mathrm{kipft}) + ((0.543\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.36863\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.36863\ \mathrm{kipft/ft})}{(0.086465\ \mathrm{kip/ft})}$$

$$E = 4.2634\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.36863\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.086465\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.36863\ \mathrm{kipft/ft})) + (4 \times (0.086465\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4241\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.086465 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2634 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.4241 \text{ ft})}{(6.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.2634 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.4241 \text{ ft})}{(6.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.64688 \text{ kip}$$

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

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

$$M_{max} = ((0.086465 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(4.2634 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.4241 \text{ ft})}{2 \times (6.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (4.2634 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.4241 \text{ ft})}{2 \times (6.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.2634 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.4241 \text{ ft})}{2 \times (6.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.8278 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.531 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.213 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.213 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$ $$s_{rebar} = Max\left[1.5, \left(1.5 \times (0.625\ \text{in})\right)\right]$$ $$s_{rebar} = 1.5\ \text{in}$$	
	Ties:	
25.7.2.2	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)	
25.7.2.1	s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), Min\left(D, b\right)\right]$$ $$s_{ties} = Min\left[\left(16 \times (0.625\ \text{in})\right), \left(48 \times (0.375\ \text{in})\right), Min\left((48\ \text{in}), (48\ \text{in})\right)\right]$$ $$s_{ties} = 10\ \text{in}$$	
	Summary: Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(11.531\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0043104$$	Status: **PASS** Ratio: **0.000**

	Shear Strength (ACI 318-19, LRFD)	
	Parameters:	
	$b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$	
	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.531 \text{ kip} \rightarrow 11531 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11531 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.02 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.02 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.02 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.02 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.1 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.0381 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.0381 \text{ kip})}{(111.1 \text{ kip})}$$

$$Ratio = 0.072353$$

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

Considering z-direction:

$V_{max} = 0.64688 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.64688 \text{ kip})}{(111.1 \text{ kip})}$$

$$Ratio = 0.0058227$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 24.143 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(24.143 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.096728$$

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

Considering z-direction:

$M_{max} = 1.8278 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.8278\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0073231$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

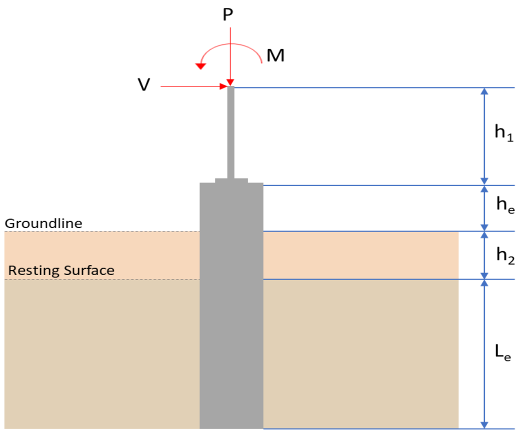
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.25\ \mathrm{ft}$ - 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)	7.227	11.531
V_x (kip)	-1.603	-2.691
V_z (kip)	-0.343	-0.544
M_x (kipft)	-1.455	-2.320
M_z (kipft)	22.713	38.290

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.603\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.25525\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.713\text{ kipft}) + ((-1.603\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 3.6167\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.8461\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.343\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.054618\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.455\text{ kipft}) + ((-0.343\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.23169\text{ kipft/ft}$$

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:
$L_{e,z} = 2.2375\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8461\text{ ft}), (2.2375\text{ ft})]$$

$$L_{e,req} = 5.846\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 6.25\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.846\text{ ft})}{(6.25\text{ ft})}$$

$$Ratio = 0.93536$$

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

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

$$q = \frac{(7.227 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.45169 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.45169 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.22584$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.25525 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.6167 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6167 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.25525 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (3.6167 \text{ kipft/ft})) + (4 \times (-0.25525 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.285 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.6167 \text{ kipft/ft})) + (3 \times (-0.25525 \text{ kip/ft}) \times (6.25 \text{ ft}))]^{\ 2}}{(6.25 \text{ ft})^2 \times [(3 \times (3.6167 \text{ kipft/ft})) + (2 \times (-0.25525 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.23493 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.6167 \text{ kipft/ft})) + ((-0.25525 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.86601 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.285 \text{ ft})}{2}$$

$$p_a = 0.32138 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23493\ \mathrm{kip/ft^2}\right)}{\left(0.32138\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.731$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.86601\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92375$$

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

Considering z-direction:

$H_o = -0.054618\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.23169\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23169\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.054618\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.23169\ \mathrm{kipft/ft})) + (4 \times (-0.054618\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4248\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.23169\ \mathrm{kipft/ft})) + (3 \times (-0.054618\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.23169\ \mathrm{kipft/ft})) + (2 \times (-0.054618\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.014739\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.23169\ \mathrm{kipft/ft})) + ((-0.054618\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.018741\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4248\ \mathrm{ft})}{2}$$

$$p_a = 0.33186\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.014739\ \mathrm{kip/ft^2}\right)}{\left(0.33186\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.044415$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

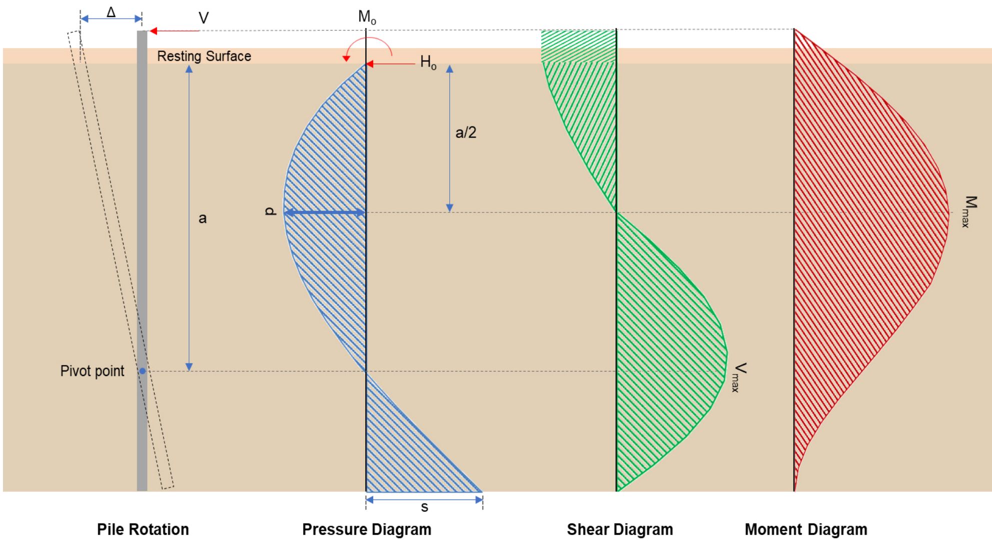
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.018741\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.019991$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.691\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.4285\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.29\ \mathrm{kipft}) + ((-2.691\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.0971\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.0971\ \mathrm{kipft/ft})}{(-0.4285\ \mathrm{kip/ft})}$$

$$E = 14.229\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.0971\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.4285\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (6.0971\ \text{kipft/ft})) + (4 \times (-0.4285\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.2846\ \text{ft}$$

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

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

$$V_{max} = ((-0.4285\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.229\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.2846\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.229\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.2846\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.0381\ \text{kip}$$

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

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

$$M_{max} = ((-0.4285\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(14.229\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.2846\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.229\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.2846\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.229\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.2846\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 24.143\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.544\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.086624\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.32\ \text{kipft}) + ((-0.544\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.36943\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.36943\ \text{kipft/ft})}{(-0.086624\ \text{kip/ft})}$$

$$E = 4.2647\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.36943\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.086624\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.36943\ \text{kipft/ft})) + (4 \times (-0.086624\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.4241\ \text{ft}$$

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

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

$$V_{max} = ((-0.086624\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2647\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4241\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.2647\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4241\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.6482\ \text{kip}$$

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

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

$$M_{max} = ((-0.086624\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(4.2647\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.4241\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.2647\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4241\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.2647\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4241\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.8316\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.531\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.213\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.213\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.531\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0043104$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.531 \text{ kip} \rightarrow 11531 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11531 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.02 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.02 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.02 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.02 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.1 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.0381 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(8.0381\ \mathrm{kip})}{(111.1\ \mathrm{kip})}$$ $$Ratio = 0.072353$$	Status: **PASS** Ratio: **0.070**
	Considering z-direction: $V_{max} = 0.6482\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.6482\ \mathrm{kip})}{(111.1\ \mathrm{kip})}$$ $$Ratio = 0.0058346$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 24.143\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(24.143\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.096728$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 1.8316\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.8316 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0073382$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

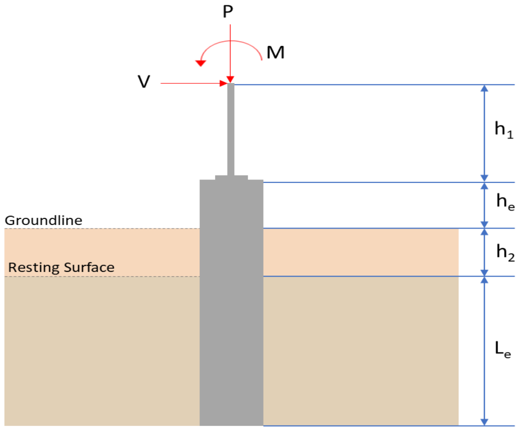
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.458	15.161
V_x (kip)	-2.063	-3.455
V_z (kip)	-0.030	-0.051
M_x (kipft)	-0.128	-0.218
M_z (kipft)	28.903	49.710

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.063\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.3285\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.903\ \text{kipft}) + ((-2.063\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.6024\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.2563\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.03\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0047771\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.128\ \text{kipft}) + ((-0.03\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.020382\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.0959\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.2563\ \text{ft}), (1.0959\ \text{ft})]$$

$$L_{e,req} = 6.256\ \text{ft}$$

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

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

$$Ratio = \frac{(6.256\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.92681$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.458\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.59112\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.59112\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.29556$$

Status: **PASS**
Ratio: **0.300**

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:

$H_o = -0.3285\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.6024\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6024\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.3285\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (4.6024\ \text{kipft/ft})) + (4 \times (-0.3285\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6367\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6024\ \text{kipft/ft})) + (3 \times (-0.3285\ \text{kip/ft}) \times (6.75\ \text{ft}))]^{\,2}}{(6.75\ \text{ft})^2 \times [(3 \times (4.6024\ \text{kipft/ft})) + (2 \times (-0.3285\ \text{kip/ft}) \times (6.75\ \text{ft}))]}$$

$$p = 0.24279\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.6024\ \text{kipft/ft})) + ((-0.3285\ \text{kip/ft}) \times (6.75\ \text{ft}))]}{(6.75\ \text{ft})^2}$$

$$s = 0.92015\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.6367\ \text{ft})}{2}$$

$$p_a = 0.34776\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24279\ \mathrm{kip/ft^2}\right)}{\left(0.34776\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.69815$$

Status: **PASS**
Ratio: **0.700**

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

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

$$Ratio = \frac{\left(0.92015\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90879$$

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

Considering z-direction:

$H_o = -0.0047771\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.020382\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.020382\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.0047771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.020382\ \mathrm{kipft/ft})) + (4 \times (-0.0047771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7887\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.020382\ \mathrm{kipft/ft})) + (3 \times (-0.0047771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\,2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.020382\ \mathrm{kipft/ft})) + (2 \times (-0.0047771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.0011384\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.020382\ \mathrm{kipft/ft})) + ((-0.0047771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.0011219\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7887\ \mathrm{ft})}{2}$$

$$p_a = 0.35916\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0011384\ \mathrm{kip/ft^2}\right)}{\left(0.35916\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0031696$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

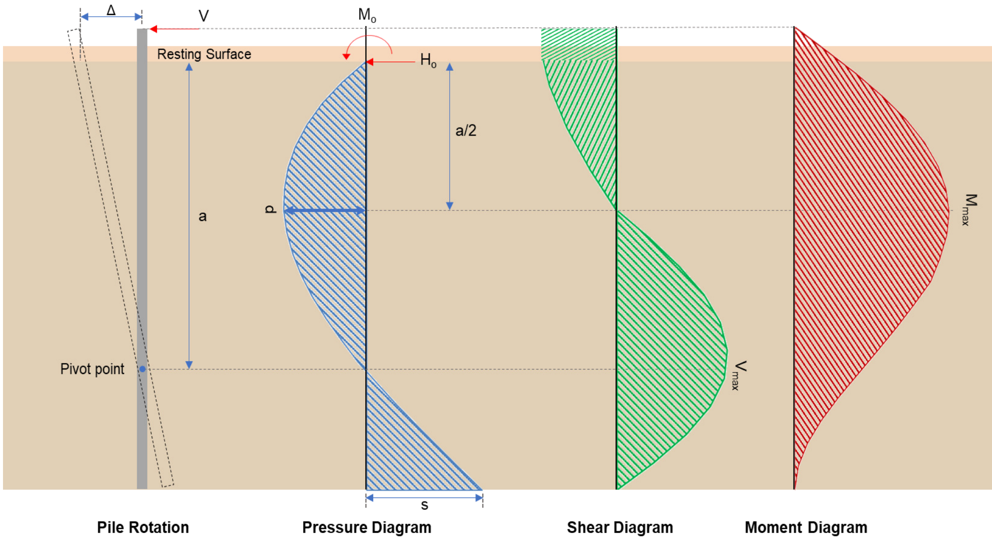
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0011219\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.001108$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.455\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.55016\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.71\ \mathrm{kipft}) + ((-3.455\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.9156\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.9156\ \mathrm{kipft/ft})}{(-0.55016\ \mathrm{kip/ft})}$$

$$E = 14.388\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9156\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.55016\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (7.9156\ \text{kipft/ft})) + (4 \times (-0.55016\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.634\ \text{ft}$$

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

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

$$V_{max} = ((-0.55016\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.388\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.634\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.388\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.634\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.7541\ \text{kip}$$

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

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

$$M_{max} = ((-0.55016\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(14.388\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.634\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.388\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.634\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.388\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.634\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.568\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.051\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.008121\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.218\ \text{kipft}) + ((-0.051\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.034713\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.034713\ \text{kipft/ft})}{(-0.008121\ \text{kip/ft})}$$

$$E = 4.2745\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.034713\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.008121\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (0.034713\ \text{kipft/ft})) + (4 \times (-0.008121\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.7885\ \text{ft}$$

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

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

$$V_{max} = ((-0.008121\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2745\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7885\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.2745\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7885\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.057969\ \text{kip}$$

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

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

$$M_{max} = ((-0.008121\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(4.2745\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.7885\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.2745\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7885\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.2745\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7885\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.17602\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.161\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.092\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.092\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	Status: PASS Ratio: 0.970
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$ $$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\ \text{in}))\right]$$ $$s_{rebar} = 1.5\ \text{in}$$ **Ties:**	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min\,((48\ \text{in}), (48\ \text{in}))\right]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(15.161\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0056673$$	Status: PASS Ratio: 0.010
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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.161 \text{ kip} \rightarrow 15161 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15161 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.51 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.51 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.51 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.51 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.41 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.7541 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(9.7541\ \text{kip})}{(111.41\ \text{kip})}$$ $$Ratio = 0.087551$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.057969\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.057969\ \text{kip})}{(111.41\ \text{kip})}$$ $$Ratio = 0.00052032$$	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:** $M_{max} = 31.568\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.568\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.12647$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.17602\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.17602\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00070522$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

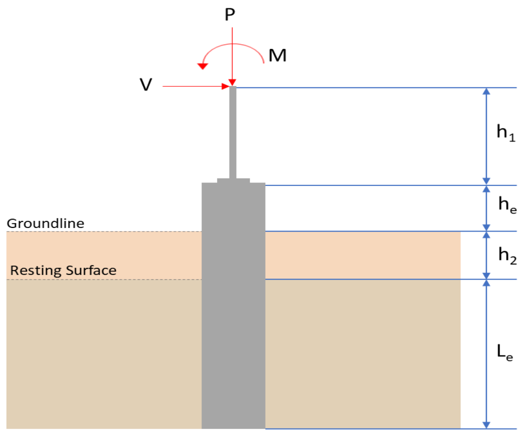
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.248	14.817
V_x (kip)	-2.046	-3.412
V_z (kip)	0.000	0.000
M_x (kipft)	-0.002	-0.003
M_z (kipft)	29.023	49.769

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.046\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.3258\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.023 \text{ kipft}) + ((-2.046 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6215 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.2748$ ft - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.002 \text{ kipft}) + ((0 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.00031847 \text{ kipft/ft}$$

L_e - Required depth of embedment in earth,

$$L_e = 2.29\,\sqrt[3]{\frac{M_o}{R}}$$

$$L_e = 2.29 \times \sqrt[3]{\frac{(0.00031847 \text{ kipft/ft})}{(150 \text{ psf/ft})}}$$

$$L_e = 0.29433 \text{ ft}$$

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.2748 \text{ ft}), (0.29433 \text{ ft})]$$

$$L_{e,req} = 6.275 \text{ ft}$$

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

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

$$Ratio = \frac{(6.275 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.92963$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.248 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.578 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.578 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.289$$

Status: **PASS**
Ratio: **0.290**

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:

$H_o = -0.3258 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 4.6215 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6215 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.3258 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (4.6215 \text{ kipft/ft})) + (4 \times (-0.3258 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6355 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6215 \text{ kipft/ft})) + (3 \times (-0.3258 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\ 2}}{(6.75 \text{ ft})^2 \times [(3 \times (4.6215 \text{ kipft/ft})) + (2 \times (-0.3258 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.24578 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.6215 \text{ kipft/ft})) + ((-0.3258 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.92759 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6355 \text{ ft})}{2}$$

$$p_a = 0.34766 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.24578 \text{ kip/ft}^2)}{(0.34766 \text{ kip/ft}^2)}$$

$$Ratio = 0.70694$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.92759 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.91614$$

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

Considering z-direction:

$H_o = 0 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.00031847 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.00031847 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (0 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.00031847 \text{ kipft/ft})) + (4 \times (0 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.5 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.00031847 \text{ kipft/ft})) + (3 \times (0 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\;2}}{(6.75 \text{ ft})^2 \times [(3 \times (0.00031847 \text{ kipft/ft})) + (2 \times (0 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.000027959 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.00031847 \text{ kipft/ft})) + ((0 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.000083877 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.5 \text{ ft})}{2}$$

$$p_a = 0.3375 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.000027959 \text{ kip/ft}^2)}{(0.3375 \text{ kip/ft}^2)}$$

$$Ratio = 0.000082842$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

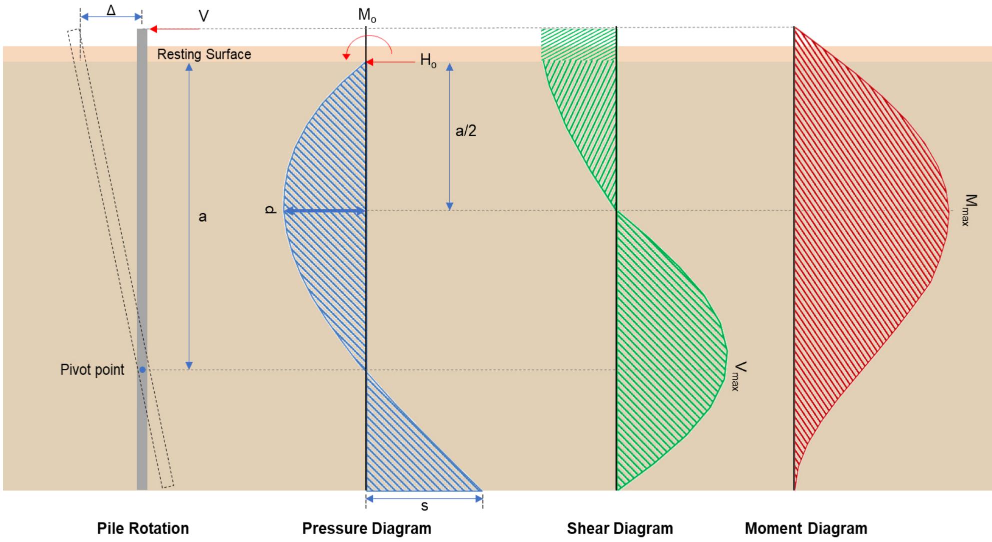
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.000083877 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.000082842$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.412 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.54331 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.769 \text{ kipft}) + ((-3.412 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.925 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.925 \text{ kipft/ft})}{(-0.54331 \text{ kip/ft})}$$

$$E = 14.586 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$(6\,M_o) + (4\,H_o\,L_e)$$

$$a = \frac{(4 \times (7.925\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.54331\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (7.925\ \mathrm{kipft/ft})) + (4 \times (-0.54331\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6326\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.54331\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.586\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6326\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.586\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6326\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.7461\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.54331\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(14.586\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6326\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.586\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6326\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.586\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6326\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.557\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.003\ \mathrm{kipft}) + ((0\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.00047771\ \mathrm{kipft/ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.00047771\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.00047771\ \mathrm{kipft/ft})) + (4 \times (0\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

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

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

$$V_{max} = 12\left(\frac{M_o\,b}{L_e}\right)\left(\frac{a}{L_e} - 1\right)\left(\frac{a}{L_e}\right)^2$$

$$V_{max} = 12 \times \left(\frac{(0.00047771\ \mathrm{kipft/ft}) \times (48\ \mathrm{in})}{(6.75\ \mathrm{ft})}\right) \times \left(\frac{(4.5\ \mathrm{ft})}{(6.75\ \mathrm{ft})} - 1\right) \times \left(\frac{(4.5\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2$$

$$V_{max} = 0.00050326\ \mathrm{kip}$$

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

$$M_{max} = (M_o\, \delta)\left[1-\left(4\,\frac{\quad}{2\,L_e}\right)+\left(3\,\frac{\quad}{2\,L_e}\right)\right]$$

$$M_{max} = ((0.00047771 \text{ kipft/ft}) \times (48 \text{ in})) \times \left[1-\left(4 \times \frac{(4.5 \text{ ft})}{2 \times (6.75 \text{ ft})}^{3}\right)+\left(3 \times \frac{(4.5 \text{ ft})}{2 \times (6.75 \text{ ft})}^{4}\right)\right]$$

$$M_{max} = 0.0016985 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.817 \text{ kip})}{(0.65)\times(0.8)}-\left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi})-(0.85 \times (2.5 \text{ ksi}))},\left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.104 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.104 \text{ in}^2\right),\left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\,0.80\,\left[\left(0.85\,f'_{ck}\,\left[A_g - A_{st}\right]\right) + \left(f_{yk}\,A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\text{ kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(14.817\text{ kip})}{(2675.2\text{ kip})}$$ $$Ratio = 0.0055387$$	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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 14.817\text{ kip} \rightarrow 14817\text{ lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(14817\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 120.46\text{ kip}$$

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

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

$$V_c = Min\left[(296.21\text{ kip}), (120.46\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 120.46\text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.46\text{ kip}) + (50.894\text{ kip}))$$

$$\phi V_n = 111.38\text{ kip}$$

Considering x-direction:

$V_{max} = 9.7461\text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.7461\text{ kip})}{(111.38\text{ kip})}$$

$$Ratio = 0.087502$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

	$$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 31.557 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.557 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.12643$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.0016985 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.0016985 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 6.8049 \times 10^{-6}$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

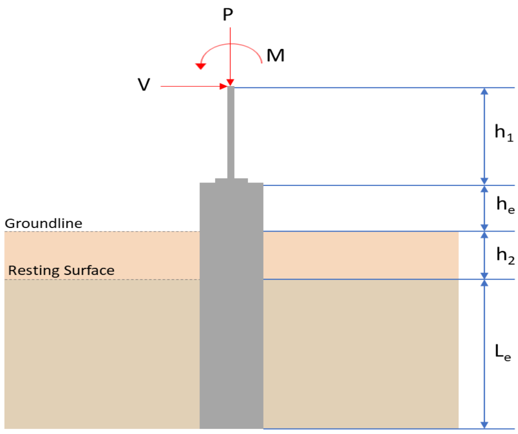
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.458	15.160
V_x (kip)	-2.063	-3.455
V_z (kip)	0.031	0.051
M_x (kipft)	0.127	0.216
M_z (kipft)	28.901	49.708

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.063\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.3285\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.901\ \text{kipft}) + ((-2.063\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.6021\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.2561\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.031\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0049363\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.127\ \text{kipft}) + ((0.031\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.020223\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.2579\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.2561\ \text{ft}), (1.2579\ \text{ft})]$$

$$L_{e,req} = 6.256\ \text{ft}$$

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

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

$$Ratio = \frac{(6.256\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.92681$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.458 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.59112 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.59112 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.29556$$

Status: **PASS**
Ratio: **0.300**

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:

$H_o = -0.3285 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 4.6021 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6021 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.3285 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (4.6021 \text{ kipft/ft})) + (4 \times (-0.3285 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6368 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6021 \text{ kipft/ft})) + (3 \times (-0.3285 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (4.6021 \text{ kipft/ft})) + (2 \times (-0.3285 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.24276 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.6021 \text{ kipft/ft})) + ((-0.3285 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.92007 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6368 \text{ ft})}{2}$$

$$p_a = 0.34776 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.24276\ \mathrm{kip/ft^2}\right)}{\left(0.34776\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.69807$$	Status: **PASS** Ratio: **0.700**
	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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.92007\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.90871$$	Status: **PASS** Ratio: **0.910**
	Considering z-direction: $H_o = 0.0049363\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.020223\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.020223\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.0049363\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.020223\ \mathrm{kipft/ft})) + (4 \times (0.0049363\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$ $$a = 4.7944\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.020223\ \mathrm{kipft/ft})) + (3 \times (0.0049363\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.020223\ \mathrm{kipft/ft})) + (2 \times (0.0049363\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$ $$p = 0.004229\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.020223\ \mathrm{kipft/ft})) + ((0.0049363\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$ $$s = 0.009714\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7944\ \mathrm{ft})}{2}$$ $$p_a = 0.35958\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.004229\ \mathrm{kip/ft^2}\right)}{\left(0.35958\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.011761$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

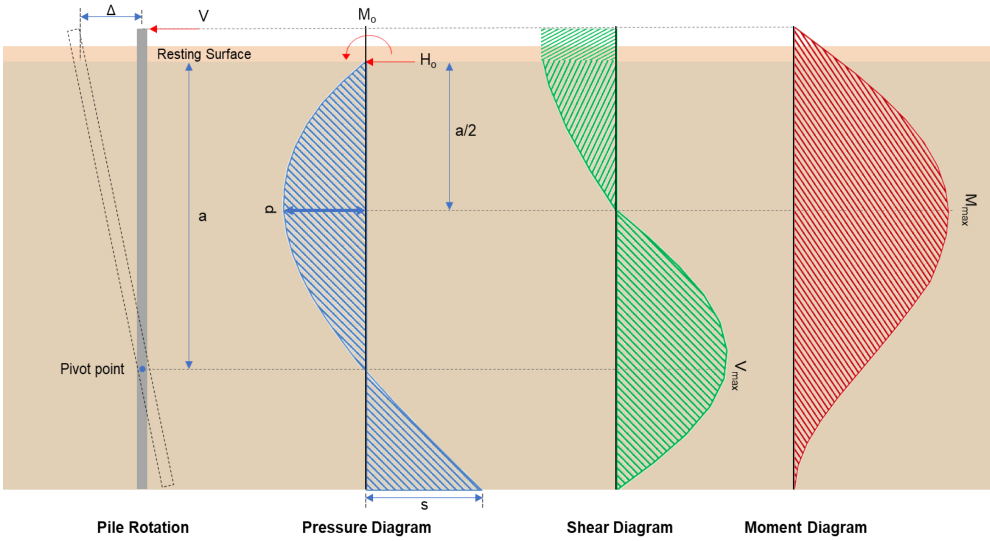
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.009714\ \mathrm{kip/ft^2})}{(1.0125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0095941$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.455\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.55016\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.708\ \mathrm{kipft}) + ((-3.455\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.9153\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.9153\ \mathrm{kipft/ft})}{(-0.55016\ \mathrm{kip/ft})}$$

$$E = 14.387\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9153\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.55016\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (7.9153\ \mathrm{kipft/ft})) + (4 \times (-0.55016\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.634\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.55016\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.387\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.634\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.387\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.634\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.7537\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.55016\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(14.387\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.634\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.387\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.634\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.387\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.634\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.567\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.051\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.008121\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.216\ \mathrm{kipft}) + ((0.051\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.034395\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.034395\ \mathrm{kipft/ft})}{(0.008121\ \mathrm{kip/ft})}$$

$$E = 4.2353\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.034395\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.008121\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.034395\ \mathrm{kipft/ft})) + (4 \times (0.008121\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7898\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.008121\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2353\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7898\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.2353\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7898\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.057638\ \text{kip}$$

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

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

$$M_{max} = ((0.008121\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(4.2353\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.7898\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.2353\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7898\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.2353\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7898\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.17491\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.16\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.092\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.092\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$Ratio = \frac{(15.16\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0056669$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.16 \text{ kip} \rightarrow 15160 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15160 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.51 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.51 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.51 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.51 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.41 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.7537 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(9.7537 \text{ kip})}{(111.41 \text{ kip})}$$ $$Ratio = 0.087548$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.057638 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.057638 \text{ kip})}{(111.41 \text{ kip})}$$ $$Ratio = 0.00051734$$	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:** $M_{max} = 31.567 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.567 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.12647$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.17491 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.17491 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00070075$$	Status: **PASS** Ratio: **0.000**