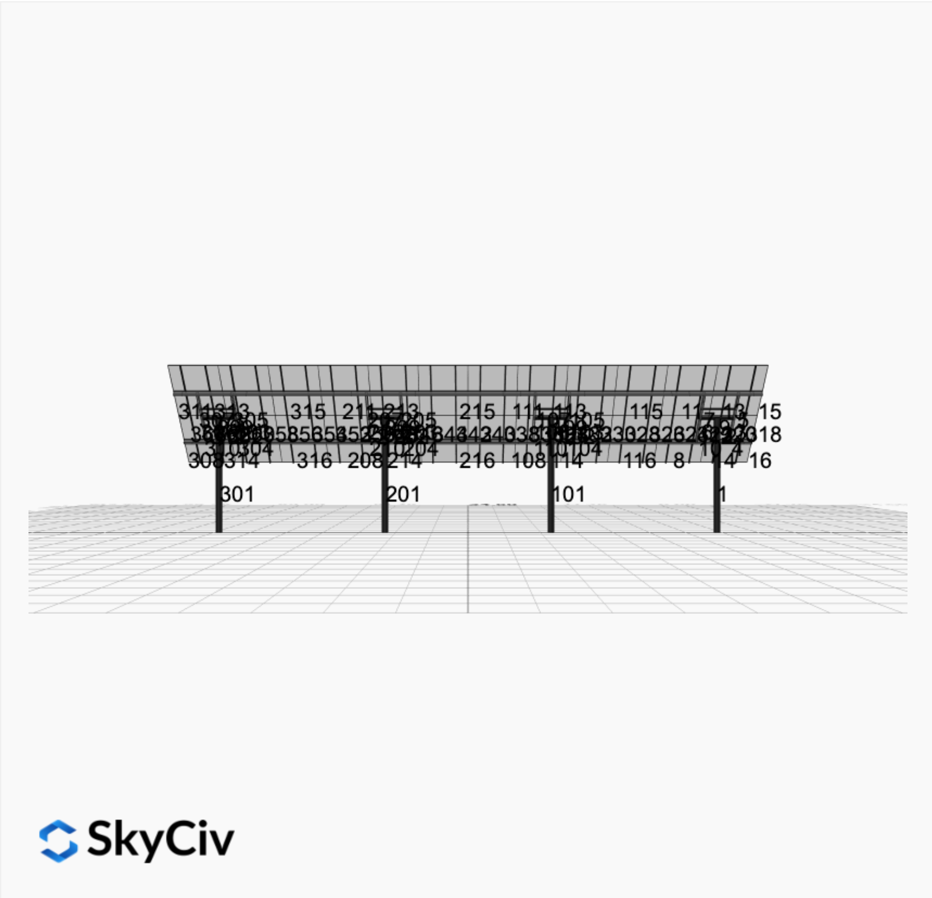
Project Details

Project Name: Randy 48mods - 48Square - V2Jb
Date: Mon Jan 27 2025
Location: 4215 E 65th S, Idaho Falls, ID 83406, USA
Number of Modules: 48
Unique ID: 4P-19.75-8TOP-SD-12-L-4Hx12W-K7FJ
Number of Poles: 4
Dealer: ______________________________
Date Sold: ______________________________



Array Dimensions N/S	15.07 ft
Array Dimensions E/W	69.00 ft
Winter Tilt Angle	48
Front Edge Clearance	8 ft

MT Solar Bill of Materials (4P-19.75-8TOP-SD-12-L-4Hx12W-K7FJ)

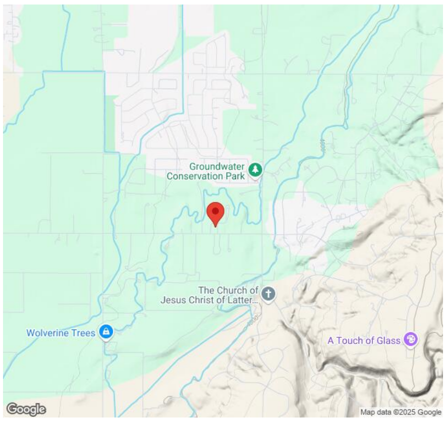
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-SD	H-Frame Assembly-SD	4
MTS-SD-Wing-12	12IN SD Wing	4
MTS-SD-Splice-90	90IN SD Splice	6
MTS-SD-Splice-57	57IN SD Splice	6
MTS-CLAMP-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (179in)	24
Rail Attachment	48
Module Mid Clamp	72

Part	Qty
Module End Clamp	48
Ground Lug	12

Site Details:



Site Address: 4215 E 65th S, Idaho Falls, ID 83406, USA

Array Specification

Duty Classification:	SD
Module Width:	44.70 in
Module Length:	68.00in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	48
Front Edge Clearance:	8
Total Array Height at Tilt:	19.20 ft
Total Frame Length:	68.75 ft
Frame Weight:	4420 lbs
Array Dimensions N/S:	15.07 ft
Array Dimensions E/W:	69.00 ft
Rail Length:	180.80 in
Rail Spacing:	2.88 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	13.60 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.25 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 6.25 ft
Foundation Volume:	15.407 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	4215 E 65th S, Idaho Falls, ID 83406, USA
Wind Speed:	99 mph

Snow Load:	64.51 psf

Design Disclaimer

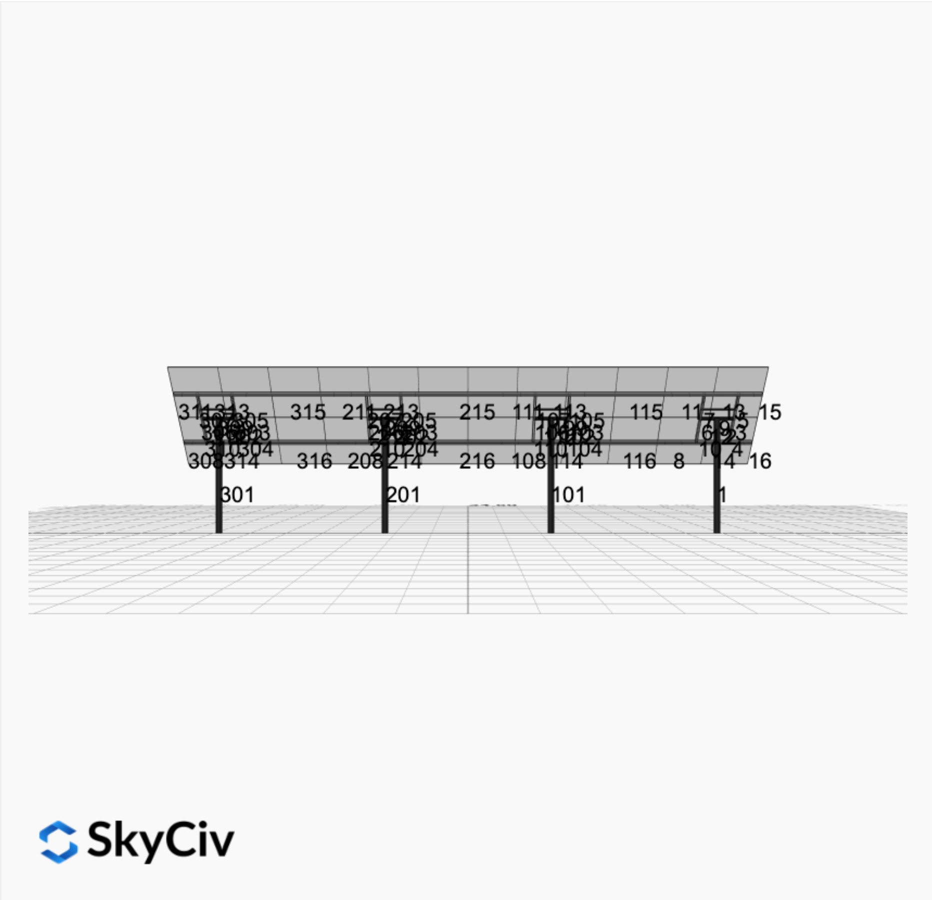
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

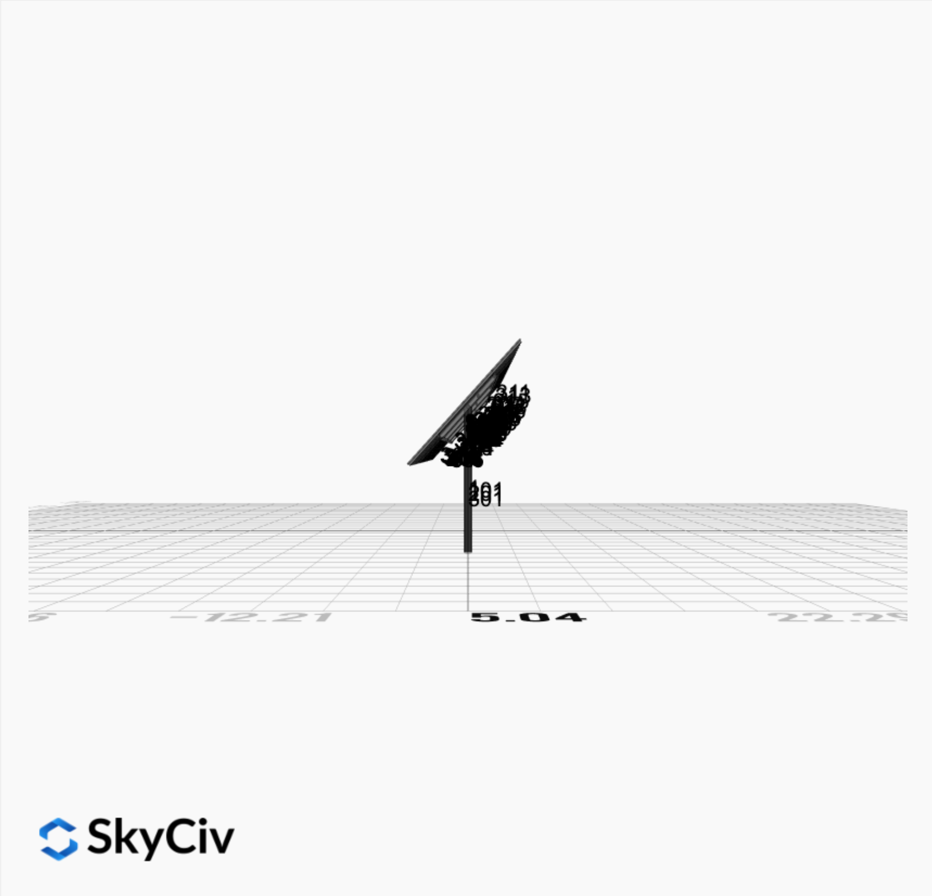
AutoDesigner Input

{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"","designer_phone":"","project_id":"Randy 48mods - 48Square - V2Jb","site_address":"4215 E 65th S, Idaho Falls, ID 83406,
USA","module_width":44.7,"module_length":68,"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":48,"ground_clearance":8,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","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)

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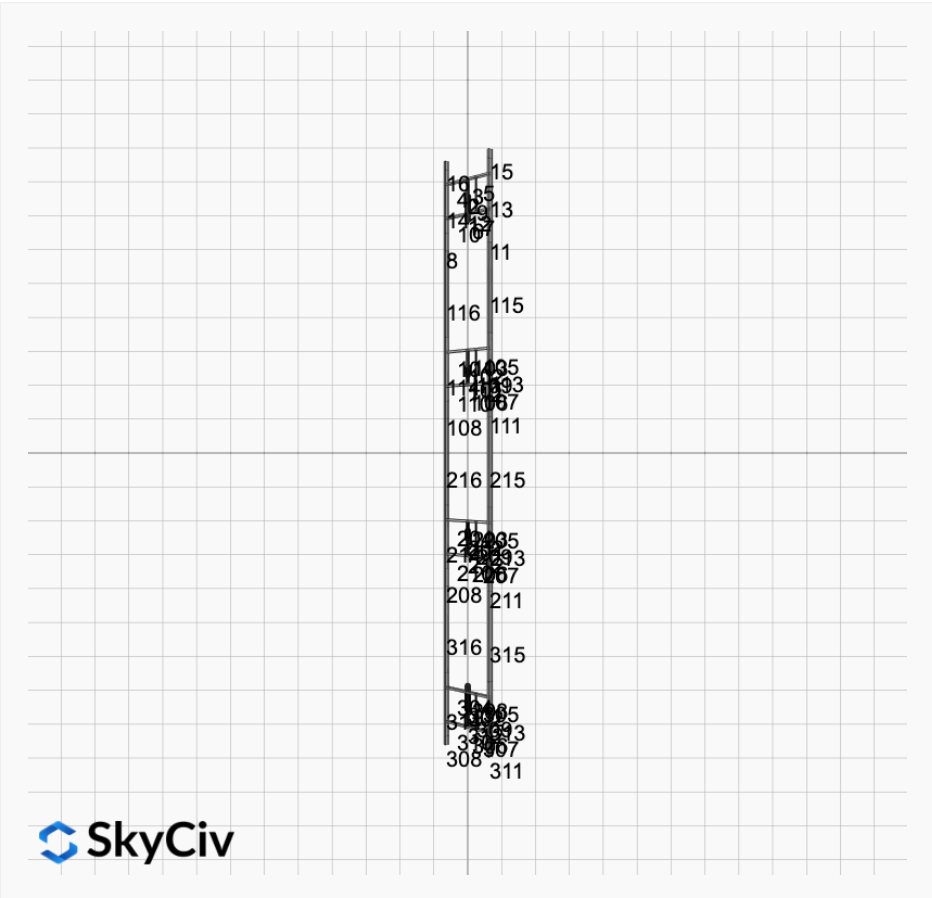
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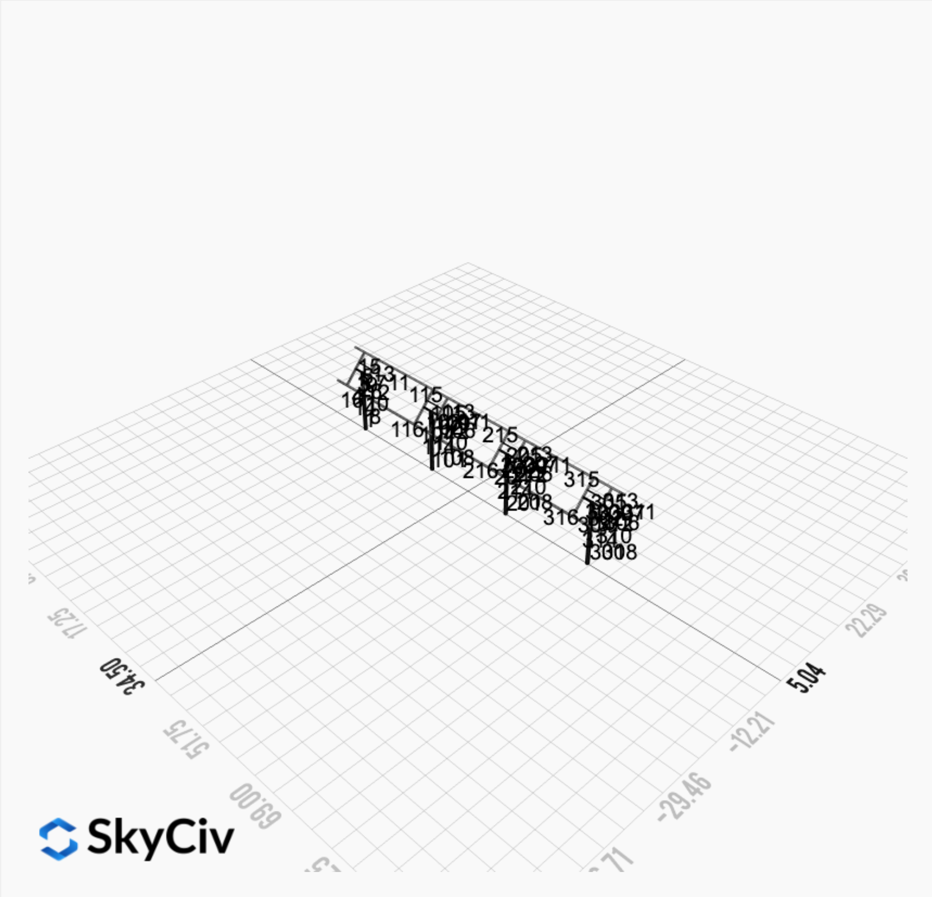
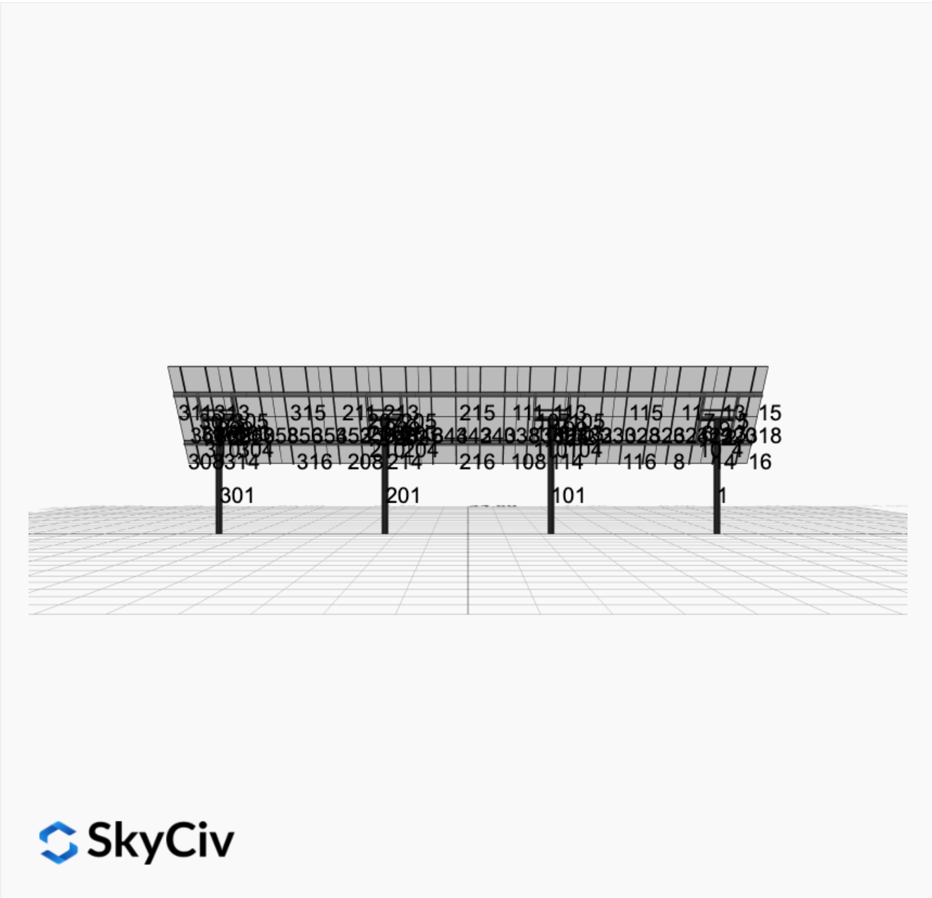
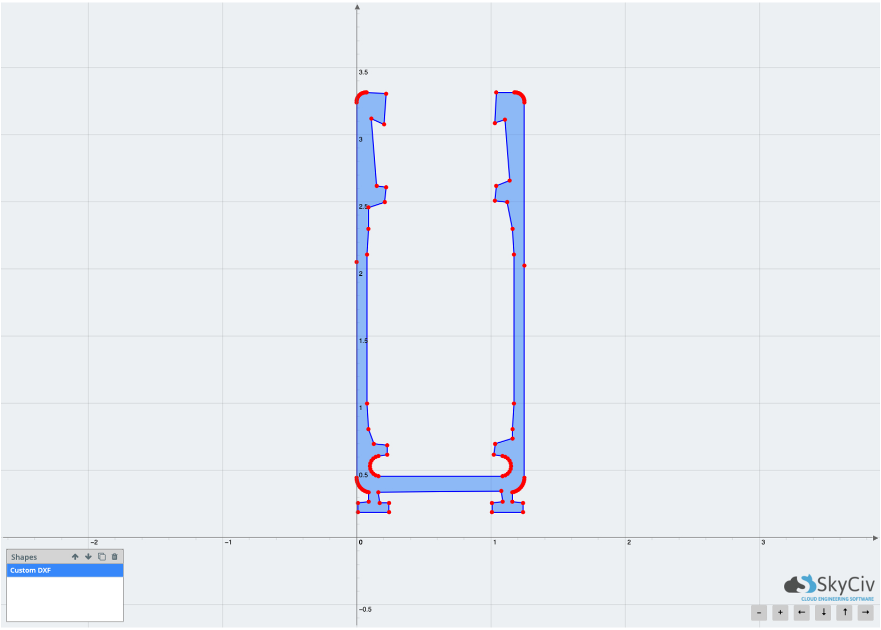


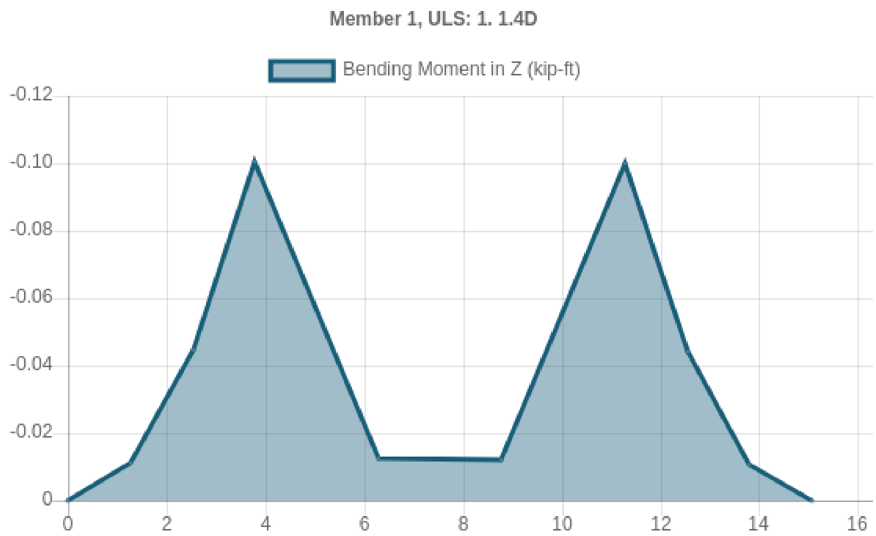


Rail Design Check

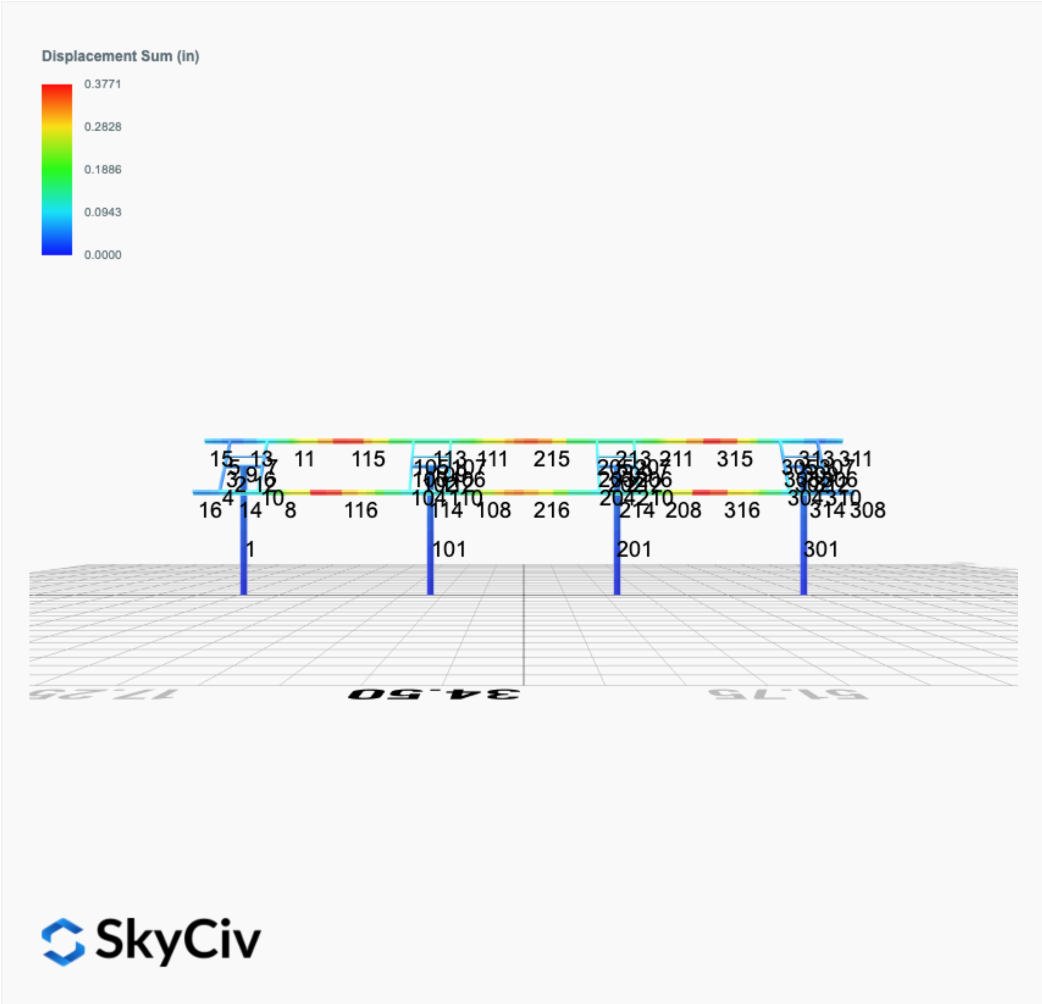
Rail Length: 15.066666666666668 ft
Additional Restraints Required: None
Tributary Width: 2.875 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0300 kip/ft
Snow (Y): -0.0333 kip/ft
Wind uplift Case A: 0.0488 kip/ft
Wind downforce Case A: 0.0488 kip/ft
Dead (Panel load) (X): 0.0090 kip/ft
Dead (Panel load) (Y): -0.0100 kip/ft

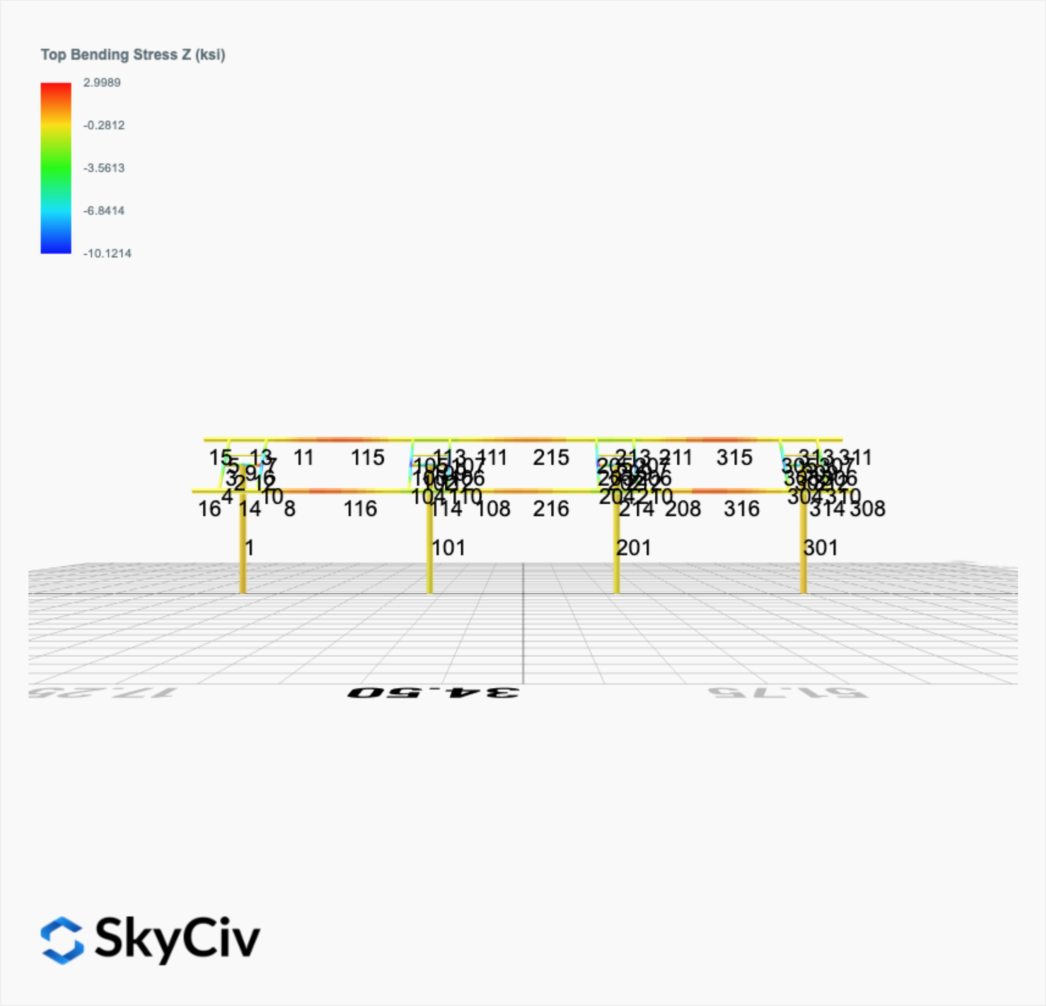


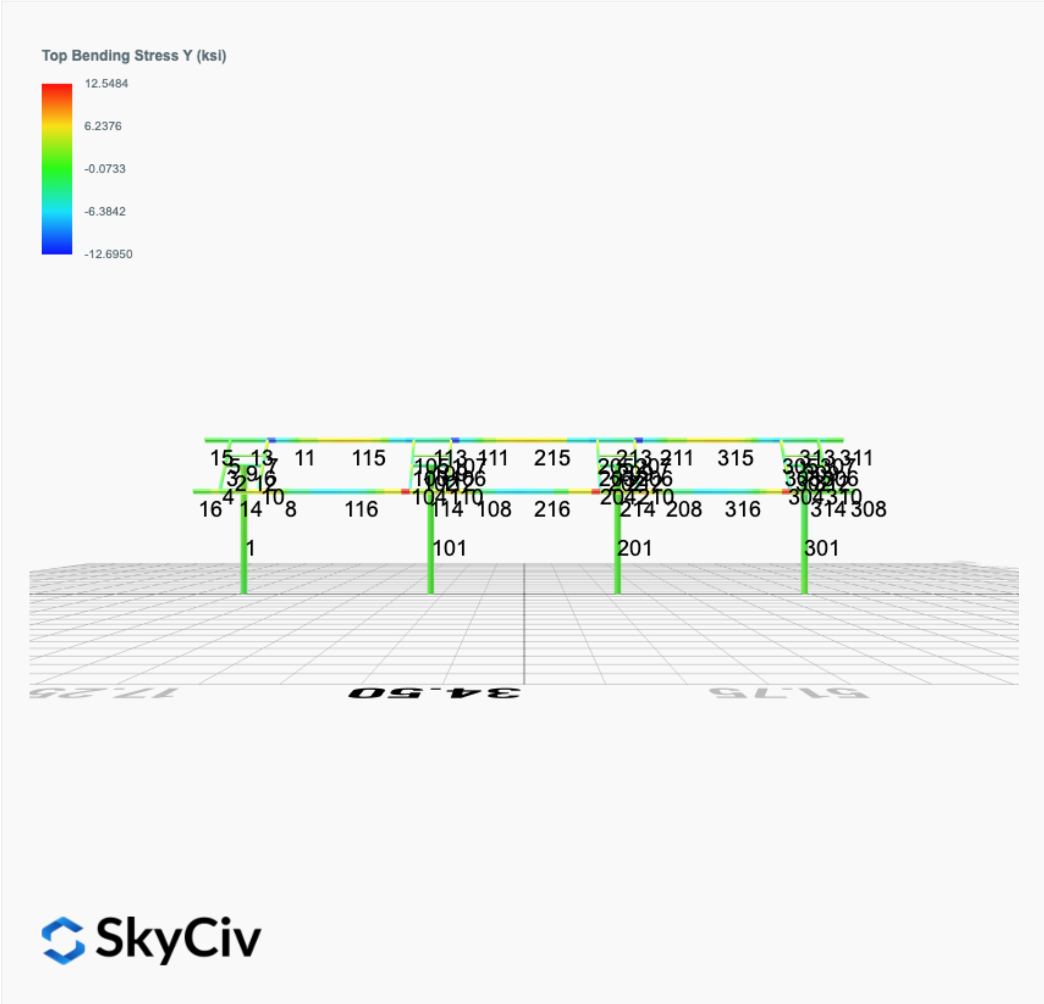
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	14.1279604	0.410	PASS
Material Yield	34.5	14.1279604	0.410	PASS
Material Strength	37	14.1279604	0.382	PASS

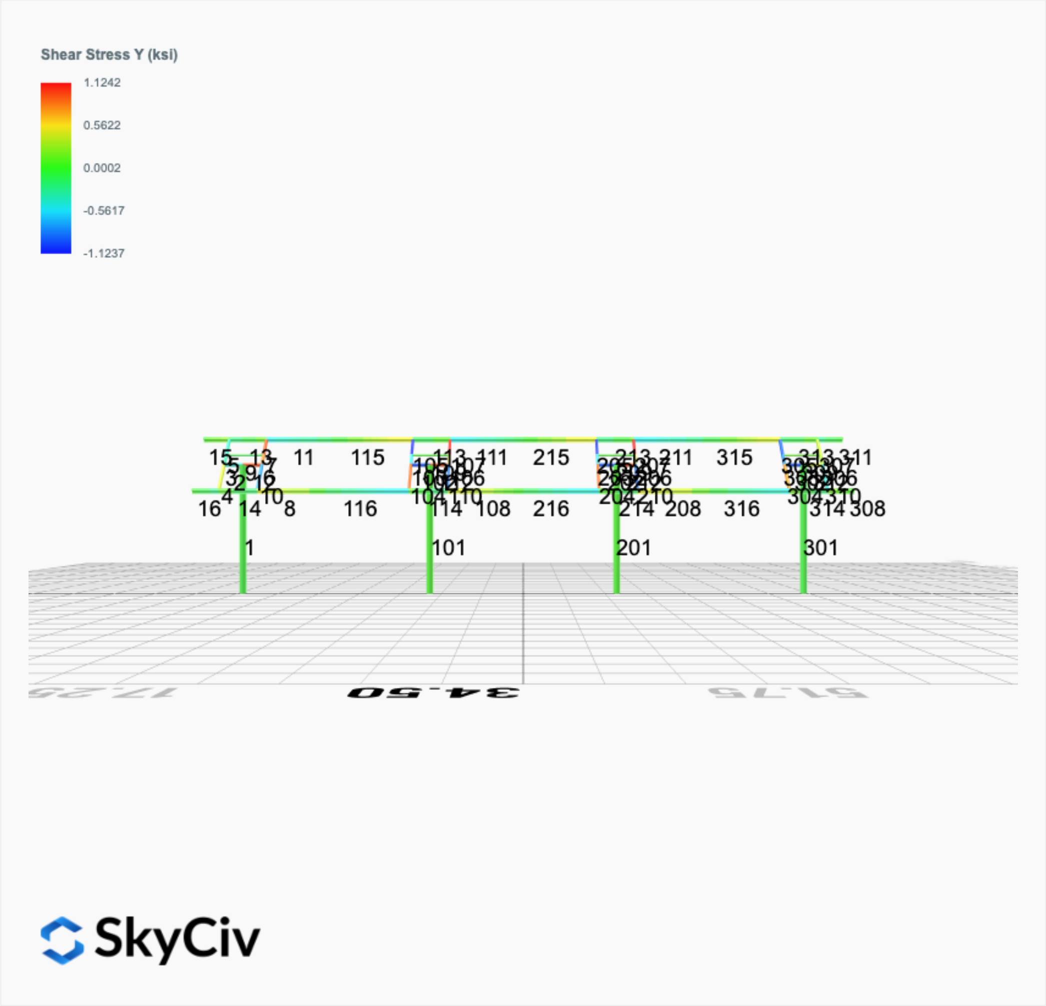


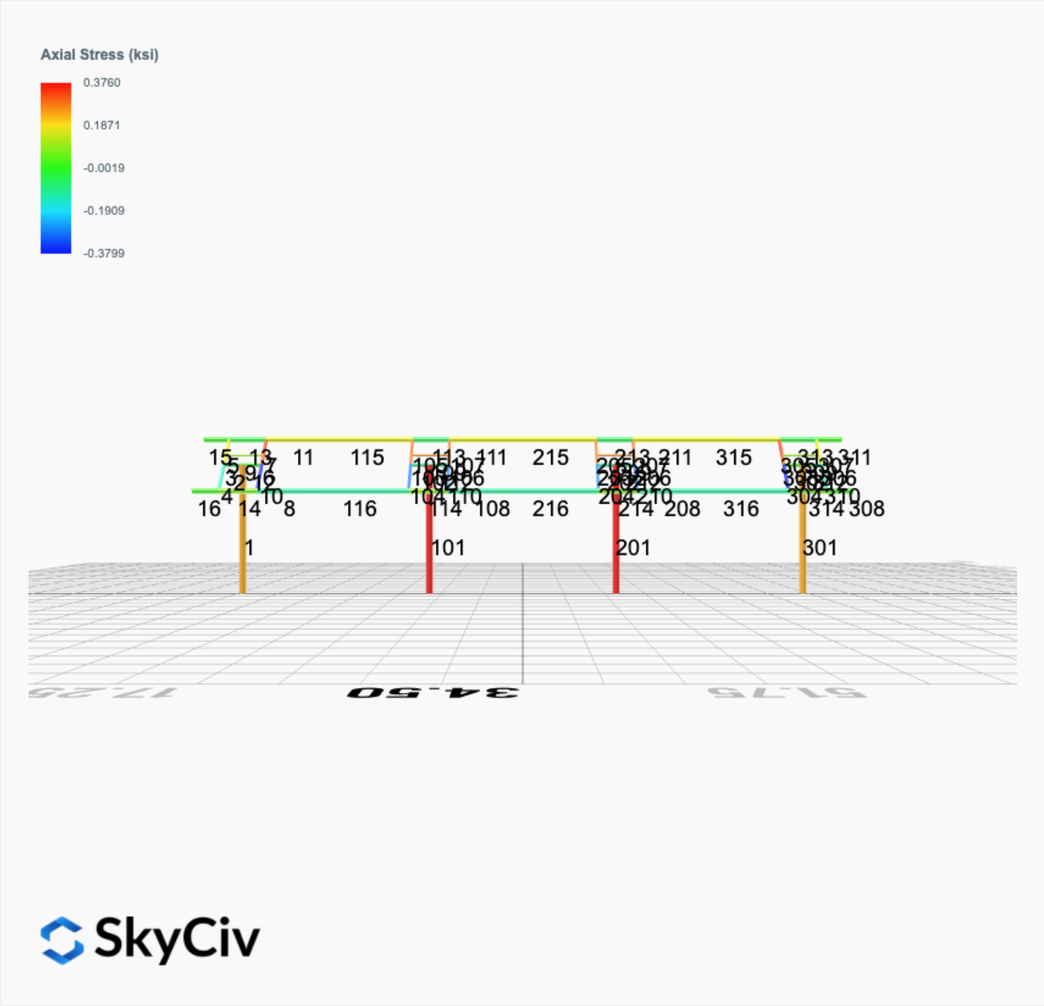
FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
2.9989
-0.2812
-3.5613
-6.8414
-10.1214
1
101
201
301
34.50


Top Bending Stress Y (ksi)
12.5484
6.2376
-0.0733
-6.3842
-12.6950
1
101
201
301
SkyCiv


Shear Stress Y (ksi)
1.1242
0.5622
0.0002
-0.5617
-1.1237
SkyCiv


Axial Stress (ksi)
0.3760
0.1871
-0.0019
-0.1909
-0.3799
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	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 2. D + L	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 3. D + (S or Lr or R)	0.0730	4.0626	0.2377	0.9948	-0.4232	-0.9282
ULS: 3. D + (S or Lr or R)	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0613	3.5001	0.1997	0.8358	-0.3555	-0.7782
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 5b. D + 0.7E	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0613	3.5001	0.1997	0.8358	-0.3555	-0.7782
ULS: 8. 0.6D + 0.7E	0.0158	1.0875	0.0515	0.2154	-0.0915	-0.1970
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6425	3.2524	0.2805	1.1360	-1.2580	22.7807
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6917	0.3739	-0.1052	-0.4024	0.9315	-22.9099
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1904	4.5800	0.3457	1.4186	-1.1846	16.5535
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0613	3.5001	0.1997	0.8358	-0.3555	-0.7782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3103	2.4211	0.0565	0.2648	0.4576	-17.7144
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0613	3.5001	0.1997	0.8358	-0.3555	-0.7782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2253	2.8924	0.2319	0.9418	-0.9816	17.0034
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2754	0.7335	-0.0574	-0.2120	0.6605	-17.2645
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0264	1.8125	0.0858	0.3590	-0.1526	-0.3283
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.6531	2.5274	0.2462	0.9925	-1.1969	22.9120
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0158	1.0875	0.0515	0.2154	-0.0915	-0.1970
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6811	-0.3511	-0.1395	-0.5460	0.9926	-22.7786
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0158	1.0875	0.0515	0.2154	-0.0915	-0.1970

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	6.9751
Shear X	-2.8337
Shear Z	0.5124
Moment X	2.1175
Moment Y (Twist)	2.1820
Moment Z	38.9313

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	4.5800
Shear X	-1.6917
Shear Z	0.3457
Moment X	1.4186
Moment Y (Twist)	1.2580
Moment Z	22.9120

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	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 2. D + L	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 3. D + (S or Lr or R)	-0.0730	5.4859	-0.0102	-0.0449	0.0309	0.9949
ULS: 3. D + (S or Lr or R)	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0614	4.6963	-0.0086	-0.0378	0.0260	0.8370

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 5b. D + 0.7E	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0614	4.6963	-0.0086	-0.0378	0.0260	0.8370
ULS: 8. 0.6D + 0.7E	-0.0159	1.3964	-0.0022	-0.0098	0.0068	0.2179
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2928	4.4308	0.0140	0.0509	-0.1593	31.4631
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2435	0.2227	-0.0193	-0.0752	0.1677	-29.8931
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7611	6.2738	0.0047	0.0127	-0.1019	24.1619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0614	4.6963	-0.0086	-0.0378	0.0260	0.8370
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6411	3.1178	-0.0203	-0.0820	0.1433	-21.8553
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0614	4.6963	-0.0086	-0.0378	0.0260	0.8370
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7262	3.9050	0.0096	0.0341	-0.1166	23.6882
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6760	0.7489	-0.0154	-0.0605	0.1286	-22.3290
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0264	2.3274	-0.0037	-0.0163	0.0113	0.3632
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2822	3.4998	0.0155	0.0574	-0.1638	31.3178
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0159	1.3964	-0.0022	-0.0098	0.0068	0.2179
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2541	-0.7082	-0.0178	-0.0687	0.1632	-30.0384
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0159	1.3964	-0.0022	-0.0098	0.0068	0.2179

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	9.5993
Shear X	-3.8284
Shear Z	-0.0356
Moment X	-0.1394
Moment Y (Twist)	0.2976
Moment Z	53.6078

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	6.2738
Shear X	-2.2928
Shear Z	-0.0203
Moment X	-0.0820
Moment Y (Twist)	0.1677
Moment Z	31.4631

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	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 2. D + L	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 3. D + (S or Lr or R)	-0.0725	5.4857	0.0106	0.0445	-0.0285	0.9880
ULS: 3. D + (S or Lr or R)	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0609	4.6961	0.0089	0.0374	-0.0240	0.8312
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 5b. D + 0.7E	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0609	4.6961	0.0089	0.0374	-0.0240	0.8312
ULS: 8. 0.6D + 0.7E	-0.0157	1.3964	0.0023	0.0097	-0.0062	0.2164
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2922	4.4300	-0.0138	-0.0485	0.1585	31.4552
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2433	0.2234	0.0193	0.0725	-0.1653	-29.8904
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607

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	-1.7604	6.2731	-0.0043	-0.0111	0.1027	24.1520
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0609	4.6961	0.0089	0.0374	-0.0240	0.8312
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6413	3.1182	0.0205	0.0797	-0.1401	-21.8572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0609	4.6961	0.0089	0.0374	-0.0240	0.8312
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7257	3.9043	-0.0094	-0.0323	0.1163	23.6816
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6759	0.7494	0.0155	0.0584	-0.1266	-22.3276
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0262	2.3273	0.0038	0.0161	-0.0104	0.3607
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2817	3.4991	-0.0153	-0.0549	0.1627	31.3109
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0157	1.3964	0.0023	0.0097	-0.0062	0.2164
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2538	-0.7075	0.0178	0.0661	-0.1611	-30.0347
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0157	1.3964	0.0023	0.0097	-0.0062	0.2164

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	9.5984
Shear X	-3.8273
Shear Z	0.0357
Moment X	0.1348
Moment Y (Twist)	0.2932
Moment Z	53.5934

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	6.2731
Shear X	-2.2922
Shear Z	0.0205
Moment X	0.0797
Moment Y (Twist)	0.1653
Moment Z	31.4552

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	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 2. D + L	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 3. D + (S or Lr or R)	0.0725	4.0625	-0.2380	-0.9980	0.4279	-0.9227
ULS: 3. D + (S or Lr or R)	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0610	3.5000	-0.2000	-0.8385	0.3595	-0.7736
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 5b. D + 0.7E	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0610	3.5000	-0.2000	-0.8385	0.3595	-0.7736
ULS: 8. 0.6D + 0.7E	0.0158	1.0875	-0.0516	-0.2161	0.0926	-0.1958
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6428	3.2528	-0.2807	-1.1353	1.2621	22.7848
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6917	0.3735	0.1051	0.3994	-0.9323	-22.9100
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1908	4.5803	-0.3461	-1.4199	1.1903	16.5598
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0610	3.5000	-0.2000	-0.8385	0.3595	-0.7736
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3100	2.4208	-0.0567	-0.2689	-0.4554	-17.7114
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0610	3.5000	-0.2000	-0.8385	0.3595	-0.7736
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2255	2.8927	-0.2320	-0.9415	0.9851	17.0071
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2753	0.7332	0.0574	0.2095	-0.6606	-17.2641
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0263	1.8125	-0.0860	-0.3601	0.1543	-0.3263

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.6533	2.5278	-0.2463	-0.9912	1.2004	22.9154
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0158	1.0875	-0.0516	-0.2161	0.0926	-0.1958
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6812	-0.3515	0.1395	0.5435	-0.9940	-22.7795
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0158	1.0875	-0.0516	-0.2161	0.0926	-0.1958

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	6.9754
Shear X	-2.8337
Shear Z	-0.5129
Moment X	-2.1204
Moment Y (Twist)	2.1896
Moment Z	38.9311

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	4.5803
Shear X	-1.6917
Shear Z	-0.3461
Moment X	-1.4199
Moment Y (Twist)	1.2621
Moment Z	22.9154

Project Details

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

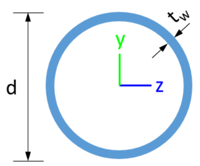
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

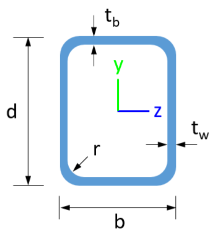
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

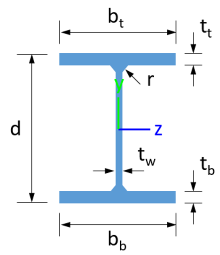
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
9	8in Pipe Sch 40	8.63	0.32					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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)

1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
15	HSS5x3x1/8	1.77	6.02	2.75	6.03	0.51	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	28.56	28.56	13.60	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.17,1.18,1.17,1.17,1.18,1.16,1.17,1.14,1.17,1.16,1.18,1.15,1.18,1.16,1.17,1.18,1.17,1.16,1.18,1.13,1.18,1.16,1.18,1.15,1.18	300	200	1
4	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.63,1.69,1.67,1.69,1.66,1.69	300	200	1
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
8	18	1.33	1.33	2.05	1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.29,1.28,1.28,1.28,1.29,1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.29,1.28,1.28,1.28,1.29,1.28	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
11	18	1.33	1.33	2.05	1.31,1.31,1.31,1.31,1.31,1.31,1.39,1.31,1.56,1.31,1.40,1.31,1.47,1.31,1.35,1.31,1.22,1.31,1.38,1.31,1.63,1.31,1.40,1.31,1.45,1.31	300	200	1
12	4	2.00	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.18,1.18,1.18,1.18,1.18,1.18,1.24,1.18,1.37,1.18,1.26,1.18,1.32,1.18,1.20,1.18,1.71,1.18,1.23,1.18,1.40,1.18,1.26,1.18,1.31,1.18	300	200	1
14	18	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.15,1.19,1.16,1.19,1.14,1.19,1.13,1.19,1.17,1.19,1.25,1.19,1.15,1.19,1.18,1.19,1.14,1.19,1.12,1.19	300	200	1
15	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	28.56	28.56	13.60	-	300	200	1
102	4	2.00	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.66,1.67,1.67,1.66,1.67,1.66,1.67,1.66,1.67,1.66,1.67,1.66,1.66,1.67,1.66,1.66,1.67,1.65,1.67,1.66,1.67,1.66,1.67	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
108	18	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.08,2.10,2.06,2.10,2.08,2.10,2.07,2.10,2.09,2.10,2.37,2.10,2.08,2.10,1.99,2.10,2.08,2.10,2.07,2.10	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
111	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,1.85,2.09,1.47,2.09,1.80,2.09,1.59,2.09,2.06,2.09,2.24,2.09,1.88,2.09,1.42,2.09,1.78,2.09,1.63,2.09	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1

113	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.10,1.07,1.19,1.07,1.11,1.07,1.14,1.07,1.09,1.07,1.04,1.07,1.10,1.07,1.25,1.07,1.11,1.07,1.13,1.07	300	200	1
114	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.11,1.07,1.08,1.07,1.10,1.07,1.07,1.07,1.04,1.07,1.08,1.07,1.12,1.07,1.09,1.07,1.09,1.07	300	200	1
115	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.11,1.15,1.09,1.15,1.11,1.15,1.09,1.15,1.13,1.15,1.23,1.15,1.12,1.15,1.08,1.15,1.11,1.15,1.09,1.15	300	200	1
116	18	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.14,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.19,1.17,1.16,1.17,1.14,1.17,1.16,1.17,1.15,1.17	300	200	1
201	9	28.56	28.56	13.60	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1
208	18	1.33	1.33	2.05	1.99,2.00,1.99,2.00,2.00,1.99,1.84,2.00,1.65,2.00,1.82,1.99,1.73,1.99,1.91,2.00,2.09,2.00,1.85,1.99,1.61,1.99,1.81,1.99,1.75,1.99	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
211	18	1.33	1.33	2.05	1.84,1.84,1.84,1.84,1.84,1.85,1.51,1.84,1.28,1.84,1.48,1.84,1.36,1.84,1.63,1.84,2.33,1.84,1.53,1.84,1.24,1.84,1.47,1.85,1.39,1.85	300	200	1
212	4	2.00	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.10,1.07,1.19,1.07,1.11,1.07,1.14,1.07,1.09,1.07,1.04,1.07,1.10,1.07,1.25,1.07,1.11,1.07,1.13,1.07	300	200	1
214	18	4.88	4.00	7.50	1.06,1.07,1.06,1.07,1.07,1.06,1.08,1.07,1.11,1.07,1.08,1.06,1.10,1.06,1.07,1.07,1.04,1.07,1.08,1.06,1.12,1.06,1.08,1.06,1.09,1.06	300	200	1
215	18	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.12,1.18,1.15,1.18,1.13,1.18,1.16,1.18,1.25,1.18,1.15,1.18,1.11,1.18,1.14,1.18,1.13,1.18	300	200	1
216	18	6.63	6.63	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18,1.18,1.18,1.20,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
301	9	28.56	28.56	13.60	-	300	200	1
302	4	2.00	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19	300	200	1
304	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
305	15	1.52	1.52	2.33	1.67,1.67,1.67,1.66,1.67,1.67,1.66,1.67,1.66,1.67,1.66,1.67,1.66,1.67,1.66,1.66,1.67,1.66,1.67,1.67,1.65,1.67,1.66,1.67,1.66,1.67	300	200	1
306	15	0.92	0.92	1.42	1.18,1.17,1.18,1.17,1.17,1.18,1.16,1.17,1.14,1.17,1.16,1.18,1.15,1.18,1.16,1.17,1.18,1.17,1.16,1.18,1.13,1.18,1.16,1.18,1.15,1.18	300	200	1
307	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1
308	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.63,1.69,1.67,1.69,1.66,1.69	300	200	1
311	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.18,1.18,1.18,1.18,1.18,1.18,1.25,1.18,1.37,1.18,1.26,1.18,1.32,1.18,1.20,1.18,1.70,1.18,1.23,1.18,1.40,1.18,1.26,1.18,1.31,1.18	300	200	1
314	18	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.15,1.19,1.16,1.19,1.14,1.19,1.13,1.19,1.17,1.19,1.25,1.19,1.15,1.19,1.18,1.19,1.14,1.19,1.12,1.19	300	200	1

315	18	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.14,1.09,1.11,1.09,1.12,1.09,1.09,1.09,1.10,1.09,1.10,1.09,1.15,1.09,1.11,1.09,1.12,1.09	300	200	1
316	18	10.20	10.20	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.09,1.08,1.09,1.08,1.09,1.08,1.09,1.09,1.09,1.09,1.09,1.08,1.09,1.08,1.09,1.08,1.09,1.08,1.09	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	139.46	83.29	83.29	113.39	113.39
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	6.26	29.14	16.61
4	79.65	72.01	10.99	6.26	29.14	16.61
5	79.65	73.44	10.99	6.26	29.14	16.61
6	79.65	74.02	10.99	6.26	29.14	16.61
7	79.65	73.44	10.99	6.26	29.14	16.61
8	120.60	115.40	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	6.26	29.14	16.61
11	120.60	115.40	23.36	6.45	30.09	45.74
12	142.83	140.22	16.17	16.17	42.85	42.85
13	120.60	84.02	20.80	6.45	30.09	45.74
14	120.60	84.02	19.78	6.45	30.09	45.74
15	120.60	113.97	23.36	6.45	30.09	45.74
16	120.60	113.97	23.36	6.45	30.09	45.74
101	377.97	139.46	83.29	83.29	113.39	113.39
102	142.83	140.22	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	6.26	29.14	16.61
104	79.65	72.01	10.99	6.26	29.14	16.61
105	79.65	73.44	10.99	6.26	29.14	16.61
106	79.65	74.02	10.99	6.26	29.14	16.61
107	79.65	73.44	10.99	6.26	29.14	16.61
108	120.60	115.40	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	6.26	29.14	16.61
111	120.60	115.40	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	84.02	18.30	6.45	30.09	45.74
114	120.60	84.02	18.34	6.45	30.09	45.74
115	120.60	68.63	14.80	6.45	30.09	45.74
116	120.60	33.17	15.53	6.45	30.09	45.74
201	377.97	139.46	83.29	83.29	113.39	113.39
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	6.26	29.14	16.61
204	79.65	72.01	10.99	6.26	29.14	16.61
205	79.65	73.44	10.99	6.26	29.14	16.61
206	79.65	74.02	10.99	6.26	29.14	16.61
207	79.65	73.44	10.99	6.26	29.14	16.61
208	120.60	115.40	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	6.26	29.14	16.61
211	120.60	115.40	23.36	6.45	30.09	45.74
212	142.83	140.22	16.17	16.17	42.85	42.85

212	142.83	140.22	16.17	16.17	42.85	42.85
213	120.60	84.02	18.28	6.45	30.09	45.74
214	120.60	84.02	18.33	6.45	30.09	45.74
215	120.60	33.17	15.20	6.45	30.09	45.74
216	120.60	68.63	15.78	6.45	30.09	45.74
301	377.97	139.46	83.29	83.29	113.39	113.39
302	142.83	140.22	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	6.26	29.14	16.61
304	79.65	72.01	10.99	6.26	29.14	16.61
305	79.65	73.44	10.99	6.26	29.14	16.61
306	79.65	74.02	10.99	6.26	29.14	16.61
307	79.65	73.44	10.99	6.26	29.14	16.61
308	120.60	113.97	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	6.26	29.14	16.61
311	120.60	113.97	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	84.02	20.79	6.45	30.09	45.74
314	120.60	84.02	19.77	6.45	30.09	45.74
315	120.60	68.63	14.82	6.45	30.09	45.74
316	120.60	33.17	14.73	6.45	30.09	45.74

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	0.050	0.467	0.058	0.025	0.005	0.507	#13	0.583	Not Required	Pass
2	0.002	0.157	0.103	0.045	0.024	0.223	#21	0.052	Not Required	Pass
3	0.008	0.316	0.038	0.029	0.005	0.340	#21	0.044	Not Required	Pass
4	0.006	0.319	0.107	0.032	0.020	0.421	#21	0.117	Not Required	Pass
5	0.007	0.196	0.046	0.032	0.009	0.204	#13	0.073	Not Required	Pass
6	0.019	0.640	0.204	0.067	0.047	0.815	#21	0.044	Not Required	Pass
7	0.020	0.397	0.314	0.064	0.061	0.441	#21	0.073	Not Required	Pass
8	0.006	0.122	0.161	0.035	0.018	0.202	#21	0.088	Not Required	Pass
9	0.005	0.066	0.113	0.006	0.007	0.145	#13	0.198	Not Required	Pass
10	0.020	0.600	0.294	0.060	0.051	0.725	#21	0.078	Not Required	Pass
11	0.007	0.108	0.166	0.038	0.018	0.191	#21	0.088	Not Required	Pass
12	0.002	0.457	0.238	0.106	0.046	0.649	#13	0.079	Not Required	Pass
13	0.010	0.077	0.424	0.049	0.023	0.450	#21	0.265	Not Required	Pass
14	0.006	0.059	0.416	0.046	0.023	0.432	#23	0.177	Not Required	Pass
15	0.000	0.004	0.010	0.006	0.003	0.014	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.010	0.006	0.003	0.014	#21	Not Required	Not Required	Pass
101	0.069	0.644	0.004	0.034	0.000	0.673	#13	0.583	Not Required	Pass
102	0.004	0.437	0.243	0.107	0.042	0.615	#21	0.053	Not Required	Pass
103	0.019	0.640	0.135	0.064	0.018	0.780	#21	0.044	Not Required	Pass
104	0.017	0.665	0.318	0.067	0.054	0.875	#21	0.078	Not Required	Pass
105	0.019	0.397	0.333	0.063	0.066	0.480	#21	0.073	Not Required	Pass
106	0.018	0.682	0.133	0.068	0.019	0.788	#21	0.044	Not Required	Pass
107	0.018	0.425	0.310	0.068	0.062	0.492	#21	0.073	Not Required	Pass
108	0.006	0.051	0.150	0.039	0.018	0.186	#21	0.088	Not Required	Pass
109	0.018	0.050	0.069	0.002	0.001	0.112	#21	0.198	Not Required	Pass
110	0.017	0.679	0.294	0.068	0.050	0.861	#21	0.078	Not Required	Pass

111	0.008	0.068	0.155	0.039	0.018	0.183	#21	0.088	Not Required	Pass
112	0.004	0.438	0.260	0.106	0.048	0.642	#13	0.034	Not Required	Pass
113	0.011	0.158	0.444	0.051	0.024	0.579	#21	0.265	Not Required	Pass
114	0.009	0.183	0.440	0.054	0.024	0.597	#21	0.265	Not Required	Pass
115	0.013	0.258	0.233	0.040	0.018	0.483	#21	0.439	Not Required	Pass
116	0.009	0.250	0.233	0.043	0.018	0.472	#21	0.675	Not Required	Pass
201	0.069	0.643	0.004	0.034	0.000	0.673	#13	0.583	Not Required	Pass
202	0.004	0.438	0.260	0.106	0.048	0.642	#13	0.034	Not Required	Pass
203	0.018	0.682	0.133	0.068	0.019	0.788	#21	0.044	Not Required	Pass
204	0.017	0.678	0.294	0.068	0.050	0.861	#21	0.078	Not Required	Pass
205	0.018	0.425	0.310	0.068	0.062	0.492	#21	0.073	Not Required	Pass
206	0.019	0.639	0.135	0.064	0.018	0.780	#21	0.044	Not Required	Pass
207	0.019	0.396	0.334	0.063	0.066	0.479	#21	0.073	Not Required	Pass
208	0.006	0.078	0.179	0.043	0.019	0.200	#21	0.088	Not Required	Pass
209	0.018	0.050	0.069	0.002	0.001	0.112	#21	0.198	Not Required	Pass
210	0.017	0.665	0.318	0.067	0.054	0.875	#21	0.078	Not Required	Pass
211	0.007	0.096	0.183	0.040	0.018	0.190	#21	0.088	Not Required	Pass
212	0.004	0.437	0.242	0.107	0.042	0.615	#21	0.053	Not Required	Pass
213	0.011	0.158	0.445	0.051	0.024	0.579	#21	0.265	Not Required	Pass
214	0.009	0.183	0.440	0.054	0.024	0.597	#21	0.265	Not Required	Pass
215	0.027	0.202	0.237	0.039	0.018	0.429	#21	0.675	Not Required	Pass
216	0.006	0.173	0.236	0.039	0.018	0.400	#21	0.439	Not Required	Pass
301	0.050	0.467	0.058	0.025	0.005	0.507	#13	0.583	Not Required	Pass
302	0.002	0.457	0.238	0.106	0.046	0.650	#13	0.079	Not Required	Pass
303	0.019	0.641	0.204	0.067	0.047	0.816	#21	0.044	Not Required	Pass
304	0.020	0.602	0.293	0.060	0.051	0.726	#21	0.078	Not Required	Pass
305	0.020	0.398	0.313	0.064	0.060	0.442	#21	0.073	Not Required	Pass
306	0.008	0.316	0.038	0.029	0.005	0.340	#21	0.044	Not Required	Pass
307	0.007	0.196	0.046	0.032	0.009	0.204	#13	0.073	Not Required	Pass
308	0.000	0.004	0.010	0.006	0.003	0.014	#21	Not Required	Not Required	Pass
309	0.005	0.066	0.114	0.006	0.007	0.146	#13	0.198	Not Required	Pass
310	0.006	0.319	0.107	0.032	0.020	0.421	#21	0.117	Not Required	Pass
311	0.000	0.004	0.010	0.006	0.003	0.014	#21	Not Required	Not Required	Pass
312	0.002	0.157	0.103	0.045	0.024	0.222	#21	0.052	Not Required	Pass
313	0.010	0.077	0.424	0.049	0.023	0.450	#21	0.177	Not Required	Pass
314	0.006	0.059	0.416	0.046	0.023	0.432	#23	0.265	Not Required	Pass
315	0.013	0.261	0.237	0.038	0.018	0.489	#21	0.439	Not Required	Pass
316	0.009	0.263	0.233	0.035	0.018	0.480	#21	0.675	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

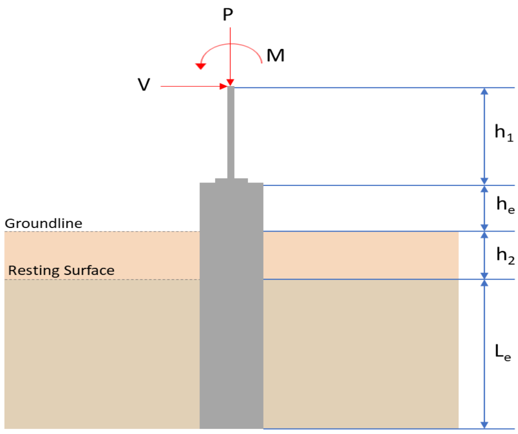
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.580	6.975
V_x (kip)	-1.692	-2.834
V_z (kip)	0.346	0.512
M_x (kipft)	1.419	2.117
M_z (kipft)	22.912	38.931

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.692 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.26943 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.912 \text{ kipft}) + ((-1.692 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.6484 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.8255 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.346 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.055096 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.419 \text{ kipft}) + ((0.346 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.22596 \text{ kipft/ft}$$

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:
$L_{e,z} = 3.0413 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8255 \text{ ft}), (3.0413 \text{ ft})]$$

$$L_{e,req} = 5.826 \text{ ft}$$

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

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

$$Ratio = \frac{(5.826 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.93216$$

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

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

$$q = \frac{(4.58 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.28625 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.28625 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.14313$$

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

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:

$H_o = -0.26943 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.6484 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6484 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (3.6484 \text{ kipft/ft})) + (4 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2892 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.6484 \text{ kipft/ft})) + (3 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 \times [(3 \times (3.6484 \text{ kipft/ft})) + (2 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.2307 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.6484 \text{ kipft/ft})) + ((-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.86214 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2892 \text{ ft})}{2}$$

$$p_a = 0.32169 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.2307\ \mathrm{kip/ft^2})}{(0.32169\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.71715$$	Status: **PASS** Ratio: **0.720**
	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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(0.86214\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.91962$$	Status: **PASS** Ratio: **0.920**

Considering z-direction:

$H_o = 0.055096\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.22596\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.22596\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.22596\ \mathrm{kipft/ft})) + (4 \times (0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4291\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.22596\ \mathrm{kipft/ft})) + (3 \times (0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.22596\ \mathrm{kipft/ft})) + (2 \times (0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.052707\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.22596\ \mathrm{kipft/ft})) + ((0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.12231\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4291\ \mathrm{ft})}{2}$$

$$p_a = 0.33219\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.052707\ \mathrm{kip/ft^2})}{(0.33219\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.15867$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

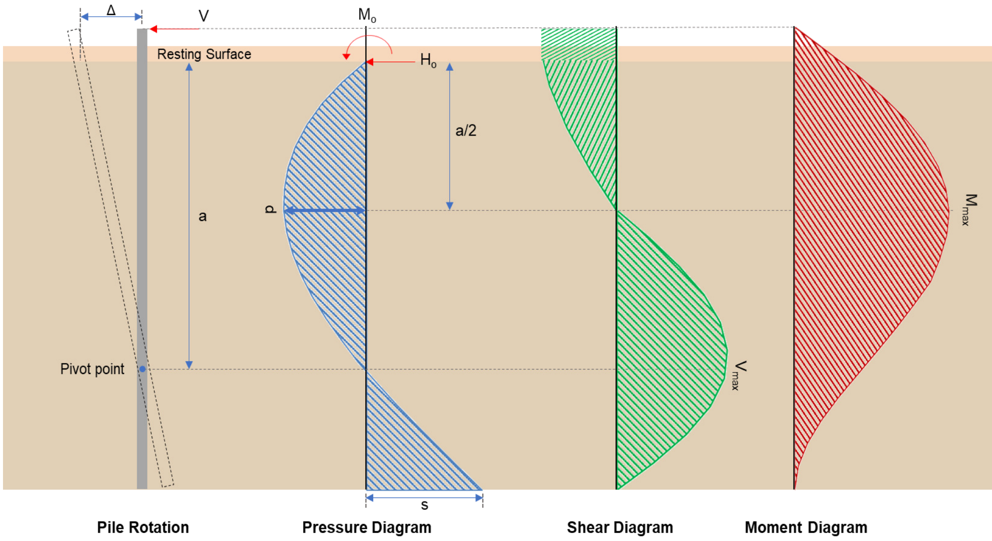
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.12231\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.13046$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.834\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.45127\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.931\ \mathrm{kipft}) + ((-2.834\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.1992\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.1992\ \mathrm{kipft/ft})}{(-0.45127\ \mathrm{kip/ft})}$$

$$E = 13.737\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.1992\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.45127\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{\cdots}$$

$$a = \frac{}{(6 \times (6.1992\ \text{kipft/ft})) + (4 \times (-0.45127\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.2879\ \text{ft}$$

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

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

$$V_{max} = ((-0.45127\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.737\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.2879\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.737\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.2879\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2134\ \text{kip}$$

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

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

$$M_{max} = ((-0.45127\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(13.737\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.2879\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (13.737\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.2879\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.737\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.2879\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 24.64\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.512\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.081529\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.117\ \text{kipft}) + ((0.512\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.3371\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.3371\ \text{kipft/ft})}{(0.081529\ \text{kip/ft})}$$

$$E = 4.1348\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.3371\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.081529\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.3371\ \text{kipft/ft})) + (4 \times (0.081529\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.4281\ \text{ft}$$

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

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

	$$V_{max} = ((0.081529\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.1348\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4281\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.1348\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4281\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$ $$V_{max} = 0.59816\ \text{kip}$$ M_{max} - Max bending moment located at depth a/2, $$M_{max} = (H_o\, b\, L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\,L_e}\right) - \left[\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{2\,L_e}\right)^3\right] + \left[\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{2\,L_e}\right)^4\right]\right]$$ $$M_{max} = ((0.081529\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(4.1348\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.4281\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.1348\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4281\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.1348\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4281\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$ $$M_{max} = 1.6867\ \text{kipft}$$	
Table 22.4.2.1 *22.4.2.2, 10.6.1.1*	**Minimum Reinforcement Check (LRFD)** **Parameters:** $f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength, $f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength, $\phi = 0.65$ - Reduction factor for axial strength, $\alpha = 0.8$ - Alpha factor for axial strength, $A_g = 2304\ \text{in}^2$ - Gross area of concrete, **Longitudinal reinforcement:** Required reinforcement due to axial load, $A_{st,required}$ $A_{st,required}$ $$A_{st,required} = Min\left[\frac{\frac{P}{\phi\,\alpha} - (0.85\, f'_{ck}\, A_g)}{f_{yk} - (0.85\, f'_{ck})}, (0.08\, A_g)\right]$$ $$A_{st,required} = Min\left[\frac{\frac{(6.975\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$ $$A_{st,required} = -84.364\ \text{in}^2$$ A_{min} - Governing minimum reinforcement area, $$A_{min} = Max\left[A_{st,required}, (0.0018\, A_g)\right]$$ $$A_{min} = Max\left[(-84.364\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$ $$A_{min} = 4.1472\ \text{in}^2$$ 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

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

$$Ratio = \frac{(6.975\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0026073$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 6.975 \text{ kip} \rightarrow 6975 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(6975 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.42 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.42 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.42 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.42 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.7 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.2134 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.2134\ \mathrm{kip})}{(110.7\ \mathrm{kip})}$$

$$Ratio = 0.074195$$

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

Considering z-direction:

$V_{max} = 0.59816\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.59816\ \mathrm{kip})}{(110.7\ \mathrm{kip})}$$

$$Ratio = 0.0054034$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 24.64\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(24.64\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.098716$$

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

Considering z-direction:

$M_{max} = 1.6867\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.6867 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0067578$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

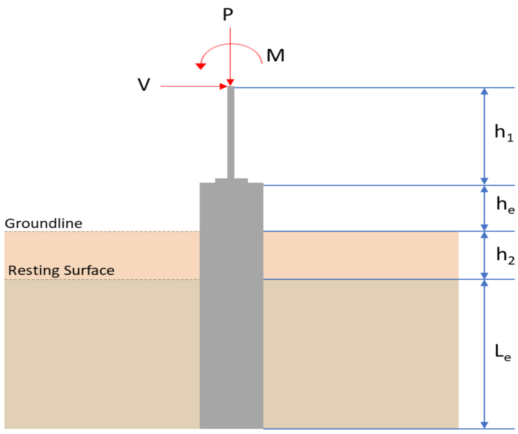
SkyCiv Foundation Design

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)	4.580	6.975
V_x (kip)	-1.692	-2.834
V_z (kip)	-0.346	-0.513
M_x (kipft)	-1.420	-2.120
M_z (kipft)	22.915	38.931

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,

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

$$H_o = \frac{(-1.692\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.26943\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.915 \text{ kipft}) + ((-1.692 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.6489 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.8258 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.346 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.055096 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.42 \text{ kipft}) + ((-0.346 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.22611 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.2094 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8258 \text{ ft}), (2.2094 \text{ ft})]$$

$$L_{e,req} = 5.826 \text{ ft}$$

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

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

$$Ratio = \frac{(5.826 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.93216$$

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

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

$$q = \frac{(4.58 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.28625 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.28625 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.14313$$

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

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:

$H_o = -0.26943 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.6489 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6489 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (3.6489 \text{ kipft/ft})) + (4 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2892 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.6489 \text{ kipft/ft})) + (3 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 \times [(3 \times (3.6489 \text{ kipft/ft})) + (2 \times (-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.23075 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.6489 \text{ kipft/ft})) + ((-0.26943 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.86229 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2892 \text{ ft})}{2}$$

$$p_a = 0.32169 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23075\ \mathrm{kip/ft^2}\right)}{\left(0.32169\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.7173$$

Status: **PASS**
Ratio: **0.720**

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

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

$$Ratio = \frac{\left(0.86229\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91977$$

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

Considering z-direction:

$H_o = -0.055096\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.22611\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.22611\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.22611\ \mathrm{kipft/ft})) + (4 \times (-0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4291\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.22611\ \mathrm{kipft/ft})) + (3 \times (-0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.22611\ \mathrm{kipft/ft})) + (2 \times (-0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = -0.03067\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.22611\ \mathrm{kipft/ft})) + ((-0.055096\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.016571\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4291\ \mathrm{ft})}{2}$$

$$p_a = 0.33218\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.03067\ \mathrm{kip/ft^2}\right)}{\left(0.33218\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.09233$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

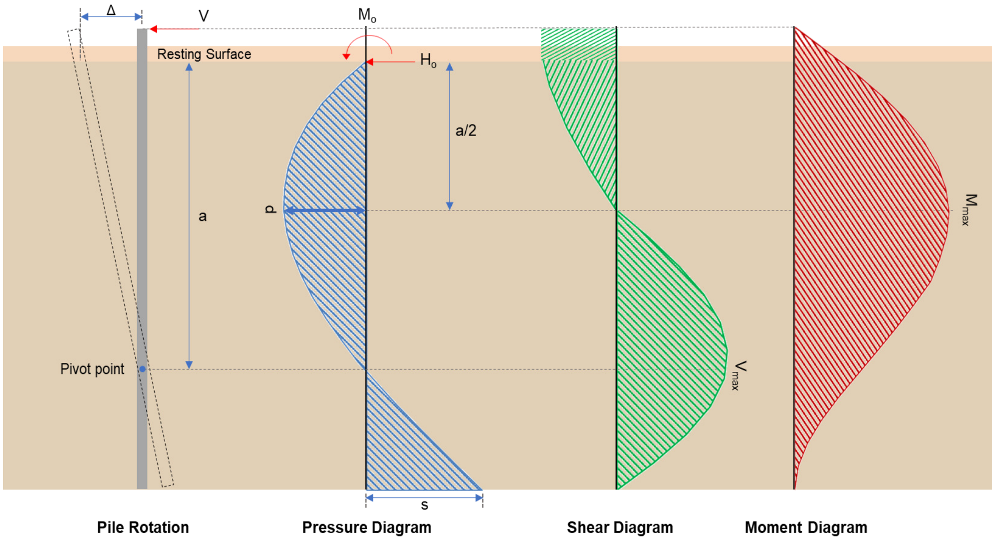
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.016571\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.017675$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.834\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.45127\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.931\ \mathrm{kipft}) + ((-2.834\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.1992\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.1992\ \mathrm{kipft/ft})}{(-0.45127\ \mathrm{kip/ft})}$$

$$E = 13.737\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.1992\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.45127\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (6.1992\ \mathrm{kipft/ft})) + (4 \times (-0.45127\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2879\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.45127\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.737\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2879\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.737\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2879\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2134\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.45127\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.25\ \mathrm{ft})) \times \left[\left(\frac{(13.737\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + \frac{(4.2879\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (13.737\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2879\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.737\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2879\ \mathrm{ft})}{2 \times (6.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 24.64\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.513\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.081688\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.12\ \mathrm{kipft}) + ((-0.513\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.33758\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.33758\ \mathrm{kipft/ft})}{(-0.081688\ \mathrm{kip/ft})}$$

$$E = 4.1326\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.33758\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.081688\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.33758\ \mathrm{kipft/ft})) + (4 \times (-0.081688\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4282\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.081688\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.1326\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4282\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.1326\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4282\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.59913\ \text{kip}$$

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

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

$$M_{max} = ((-0.081688\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(4.1326\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.4282\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.1326\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4282\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.1326\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4282\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.6894\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(6.975\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.364\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.364\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.975\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0026073$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 6.975 \text{ kip} \rightarrow 6975 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(6975 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.42 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.42 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.42 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.42 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.7 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.2134 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.2134 \text{ kip})}{(110.7 \text{ kip})}$$

$$Ratio = 0.074195$$

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

Considering z-direction:

$V_{max} = 0.59913 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.59913 \text{ kip})}{(110.7 \text{ kip})}$$

$$Ratio = 0.0054121$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 24.64 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(24.64 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.098716$$

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

Considering z-direction:

$M_{max} = 1.6894 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.6894\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0067684$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

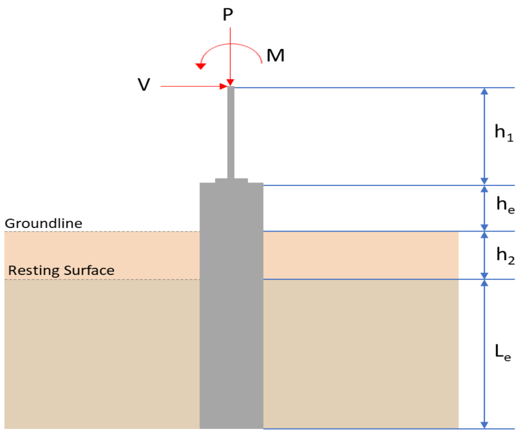
SkyCiv Foundation Design

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)	6.274	9.599
V_x (kip)	-2.293	-3.828
V_z (kip)	-0.020	-0.036
M_x (kipft)	-0.082	-0.139
M_z (kipft)	31.463	53.608

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,

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

$$H_o = \frac{(-2.293\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.36513\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.463\ \text{kipft}) + ((-2.293\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.01\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.3893\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.082\ \text{kipft}) + ((-0.02\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.013057\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.95212\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3893\ \text{ft}), (0.95212\ \text{ft})]$$

$$L_{e,req} = 6.389\ \text{ft}$$

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

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

$$Ratio = \frac{(6.389\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.94652$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.274\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.39213\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.39213\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.19606$$

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

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:

$H_o = -0.36513\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.01\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.01\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.36513\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (5.01\ \text{kipft/ft})) + (4 \times (-0.36513\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6389\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.01\ \text{kipft/ft})) + (3 \times (-0.36513\ \text{kip/ft}) \times (6.75\ \text{ft}))]^{\ 2}}{(6.75\ \text{ft})^2 \times [(3 \times (5.01\ \text{kipft/ft})) + (2 \times (-0.36513\ \text{kip/ft}) \times (6.75\ \text{ft}))]}$$

$$p = 0.26063\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.01\ \text{kipft/ft})) + ((-0.36513\ \text{kip/ft}) \times (6.75\ \text{ft}))]}{(6.75\ \text{ft})^2}$$

$$s = 0.99496\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.6389\ \text{ft})}{2}$$

$$p_a = 0.34792\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26063\ \mathrm{kip/ft^2}\right)}{\left(0.34792\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.74911$$

Status: **PASS**
Ratio: **0.750**

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

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

$$Ratio = \frac{\left(0.99496\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.98267$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = -0.0031847\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.013057\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.013057\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.013057\ \mathrm{kipft/ft})) + (4 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7943\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.013057\ \mathrm{kipft/ft})) + (3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.013057\ \mathrm{kipft/ft})) + (2 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.00064754\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.013057\ \mathrm{kipft/ft})) + ((-0.0031847\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.00060811\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7943\ \mathrm{ft})}{2}$$

$$p_a = 0.35957\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00064754\ \mathrm{kip/ft^2}\right)}{\left(0.35957\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0018008$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

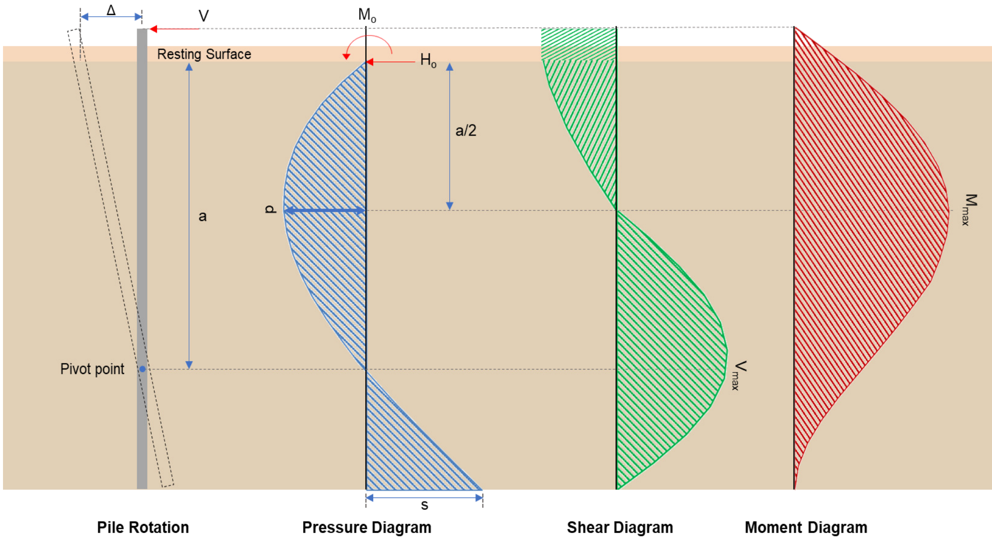
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00060811\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0006006$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.828\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.60955\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.608\ \mathrm{kipft}) + ((-3.828\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.5363\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.5363\ \mathrm{kipft/ft})}{(-0.60955\ \mathrm{kip/ft})}$$

$$E = 14.004\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.5363\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.60955\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{\cdots}$$

$$a = \frac{}{(6 \times (8.5363\ \mathrm{kipft/ft})) + (4 \times (-0.60955\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

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

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

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

$$V_{max} = ((-0.60955\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.004\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6368\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.004\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6368\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.561\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.60955\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(14.004\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6368\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.004\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6368\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.004\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6368\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 34.147\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.036\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0057325\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.139\ \mathrm{kipft}) + ((-0.036\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.022134\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.022134\ \mathrm{kipft/ft})}{(-0.0057325\ \mathrm{kip/ft})}$$

$$E = 3.8611\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.022134\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.0057325\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.022134\ \mathrm{kipft/ft})) + (4 \times (-0.0057325\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8027\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0057325 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8611 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8027 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8611 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8027 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.038456 \text{ kip}$$

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

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

$$M_{max} = ((-0.0057325 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(3.8611 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8027 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.8611 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8027 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8611 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8027 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.11596 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.6 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.277 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.277 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

$$Ratio = \frac{(9.6\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0035882$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.6 \text{ kip} \rightarrow 9600 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(9600 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.77 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.77 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.77 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.77 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.93 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.561 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.561\ \mathrm{kip})}{(110.93\ \mathrm{kip})}$$

$$Ratio = 0.095209$$

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

Considering z-direction:

$V_{max} = 0.038456\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.038456\ \mathrm{kip})}{(110.93\ \mathrm{kip})}$$

$$Ratio = 0.00034668$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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:

$M_{max} = 34.147\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(34.147\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.13681$$

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

Considering z-direction:

$M_{max} = 0.11596\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

		$$Ratio = \frac{(0.11596 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00046458$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

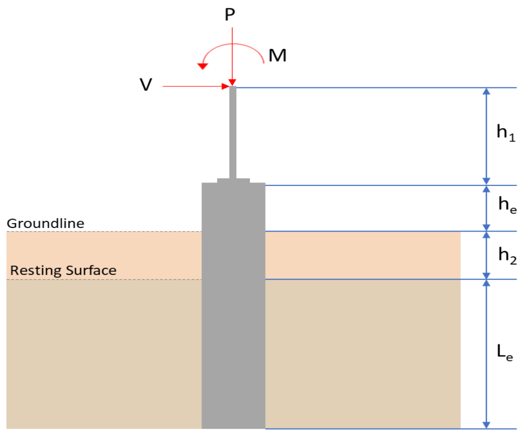
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.273	9.598
V_x (kip)	-2.292	-3.827
V_z (kip)	0.021	0.036
M_x (kipft)	0.080	0.135
M_z (kipft)	31.455	53.593

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.292 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.36497 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.455\ \text{kipft}) + ((-2.292\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.0088\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.389\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.021\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0033439\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.08\ \text{kipft}) + ((0.021\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.012739\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.0726\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.389\ \text{ft}), (1.0726\ \text{ft})]$$

$$L_{e,req} = 6.389\ \text{ft}$$

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

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

$$Ratio = \frac{(6.389\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.94652$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.273 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.39206 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39206 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.19603$$

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

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:

$H_o = -0.36497 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.0088 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.0088 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.36497 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (5.0088 \text{ kipft/ft})) + (4 \times (-0.36497 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6389 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.0088 \text{ kipft/ft})) + (3 \times (-0.36497 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\,2}}{(6.75 \text{ ft})^2 \times [(3 \times (5.0088 \text{ kipft/ft})) + (2 \times (-0.36497 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.26059 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.0088 \text{ kipft/ft})) + ((-0.36497 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.99476 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6389 \text{ ft})}{2}$$

$$p_a = 0.34792 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26059\ \mathrm{kip/ft^2}\right)}{\left(0.34792\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.74901$$

Status: **PASS**
Ratio: **0.750**

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

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

$$Ratio = \frac{\left(0.99476\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.98248$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.012739\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.012739\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.0033439\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.012739\ \mathrm{kipft/ft})) + (4 \times (0.0033439\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8046\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.012739\ \mathrm{kipft/ft})) + (3 \times (0.0033439\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\,2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.012739\ \mathrm{kipft/ft})) + (2 \times (0.0033439\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.0027809\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.012739\ \mathrm{kipft/ft})) + ((0.0033439\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.0063275\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8046\ \mathrm{ft})}{2}$$

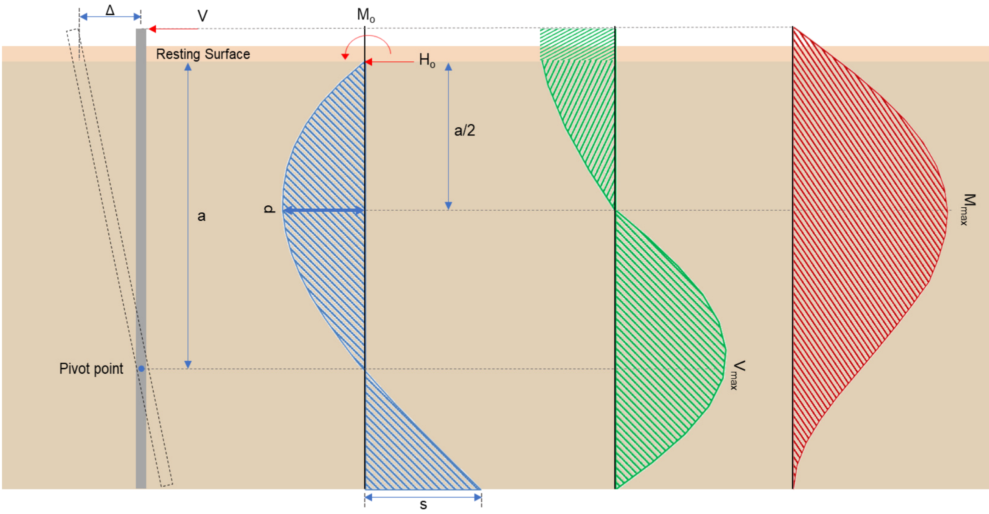
$$p_a = 0.36035\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0027809\ \mathrm{kip/ft^2}\right)}{\left(0.36035\ \mathrm{kip/ft^2}\right)}$$

	$$Ratio = 0.0077172$$ 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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(0.0063275\ \mathrm{kip/ft^2})}{(1.0125\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.0062494$$	Status: **PASS** Ratio: **0.010** Status: **PASS** Ratio: **0.010**	



Pile Rotation Pressure Diagram Shear Diagram Moment Diagram

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.827\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.60939\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.593\ \mathrm{kipft}) + ((-3.827\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.5339\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.5339\ \mathrm{kipft/ft})}{(-0.60939\ \mathrm{kip/ft})}$$

$$E = 14.004\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.5339\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.60939\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (8.5339\ \text{kipft/ft})) + (4 \times (-0.60939\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

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

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

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

$$V_{max} = ((-0.60939\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.004\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6368\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.004\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6368\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.559\ \text{kip}$$

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

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

$$M_{max} = ((-0.60939\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(14.004\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.6368\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.004\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6368\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.004\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6368\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 34.138\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.036\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0057325\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.135\ \text{kipft}) + ((0.036\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.021497\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.021497\ \text{kipft/ft})}{(0.0057325\ \text{kip/ft})}$$

$$E = 3.75\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.021497\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (0.0057325\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (0.021497\ \text{kipft/ft})) + (4 \times (0.0057325\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.8068\ \text{ft}$$

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

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

$$V_{max} = ((0.0057325\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.75\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8068\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.75\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8068\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.037795\ \text{kip}$$

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

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

$$M_{max} = ((0.0057325\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(3.75\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.8068\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.75\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.8068\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.75\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.8068\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.11373\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.598\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.277\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.277\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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,

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

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

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

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,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(9.598\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0035878$$

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

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.598 \text{ kip} \rightarrow 9598 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(9598 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.77 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.77 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.77 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.77 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.93 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.559 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.559 \text{ kip})}{(110.93 \text{ kip})}$$

$$Ratio = 0.095183$$

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

Considering z-direction:

$V_{max} = 0.037795 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.037795 \text{ kip})}{(110.93 \text{ kip})}$$

$$Ratio = 0.00034071$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 34.138 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(34.138 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.13677$$

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

Considering z-direction:

$M_{max} = 0.11373 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.11373 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00045566$$	Status: **PASS** Ratio: **0.000**	