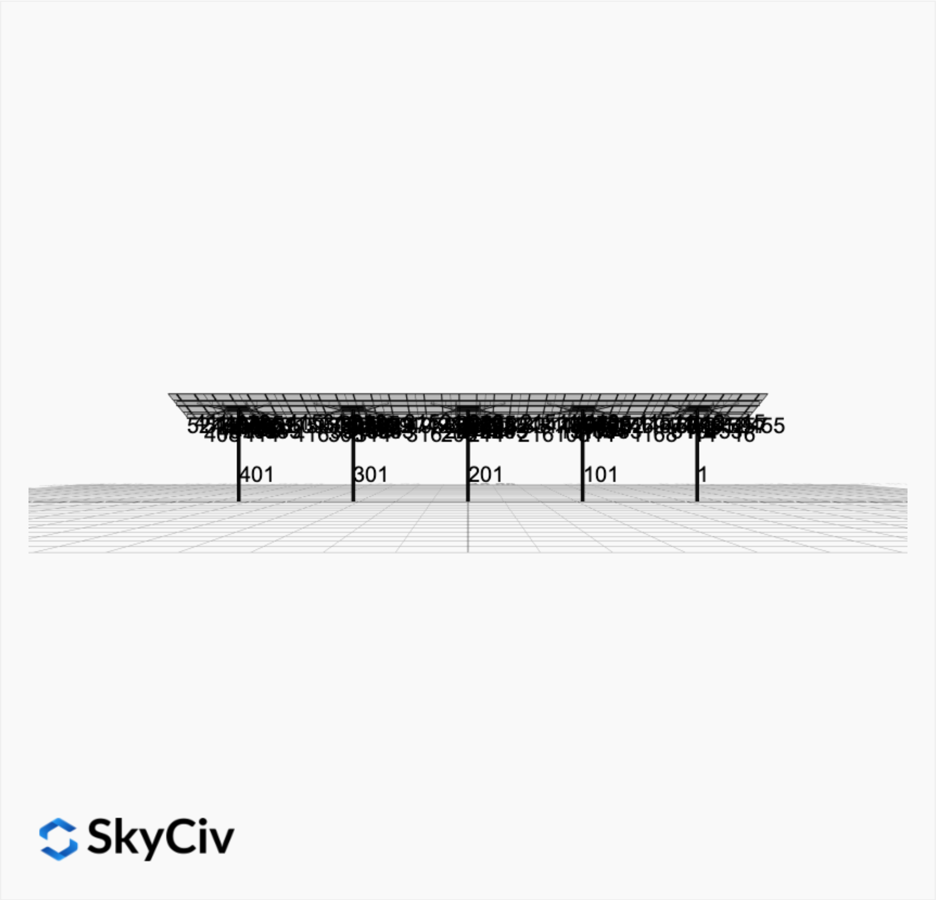
Project Details

Project Name: SMPA Ridgway 375w 4x17 - 1975ft - V1Jb
Location: 720 N Railroad St, Ridgway, CO 81432, USA
Unique ID: 5P-19.75-6TOP-XD-72-L-4Hx17W-STRUTS-EF1J
Dealer: ______________________________

Date: Mon Feb 03 2025
Number of Modules: 68
Number of Poles: 5
Date Sold: ______________________________



Array Dimensions N/S	13.95 ft
Array Dimensions E/W	99.92 ft
Winter Tilt Angle	15
Front Edge Clearance	14 ft

MT Solar Bill of Materials (5P-19.75-6TOP-XD-72-L-4Hx17W-STRUTS-EF1J)

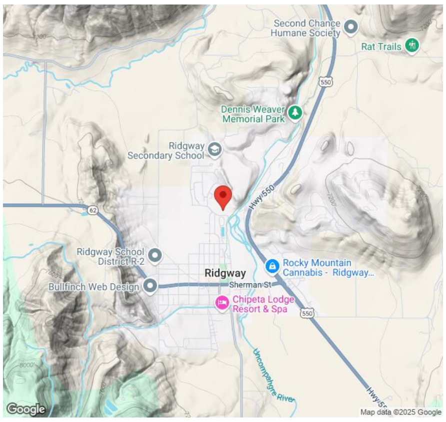
Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	5
MTS-HF-XD	H-Frame Assembly-XD	5
MTS-XD-Wing-72	72IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	8
MTS-XD-Splice-57	57IN XD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	17

Rail Bill of Materials

Part	Qty
Rails (165in)	34

Part	Qty
Rail Attachment	68
Module Mid Clamp	102
Module End Clamp	68
Ground Lug	17

Site Details:



Site Address: 720 N Railroad St, Ridgway, CO 81432, USA

Array Specification

Duty Classification:	XD
Module Width:	41.34 in
Module Length:	69.53in
Number of Rows:	4
Number of Columns:	17
Total Number of Modules:	68
Winter Tilt Angle:	15
Front Edge Clearance:	14
Total Array Height at Tilt:	17.61 ft
Total Frame Length:	98.50 ft
Frame Weight:	6916 lbs
Array Dimensions N/S:	13.95 ft
Array Dimensions E/W:	99.92 ft
Rail Length:	167.36 in
Rail Spacing:	2.94 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	15.80 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.00 ft Pile 2: 5.00 ft Pile 3: 5.00 ft Pile 4: 5.00 ft Pile 5: 5.00 ft
Foundation Volume:	14.815 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	720 N Railroad St, Ridgway, CO 81432, USA
Wind Speed:	98 mph

Snow Load:	52 psf

Design Disclaimer

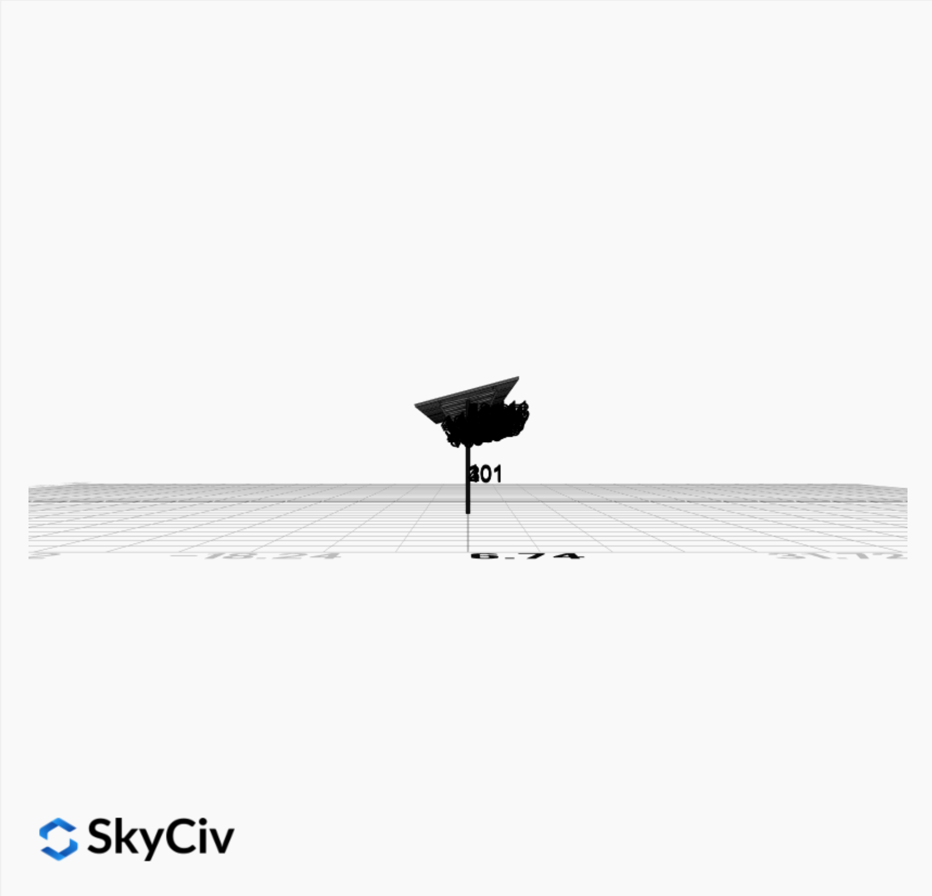
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

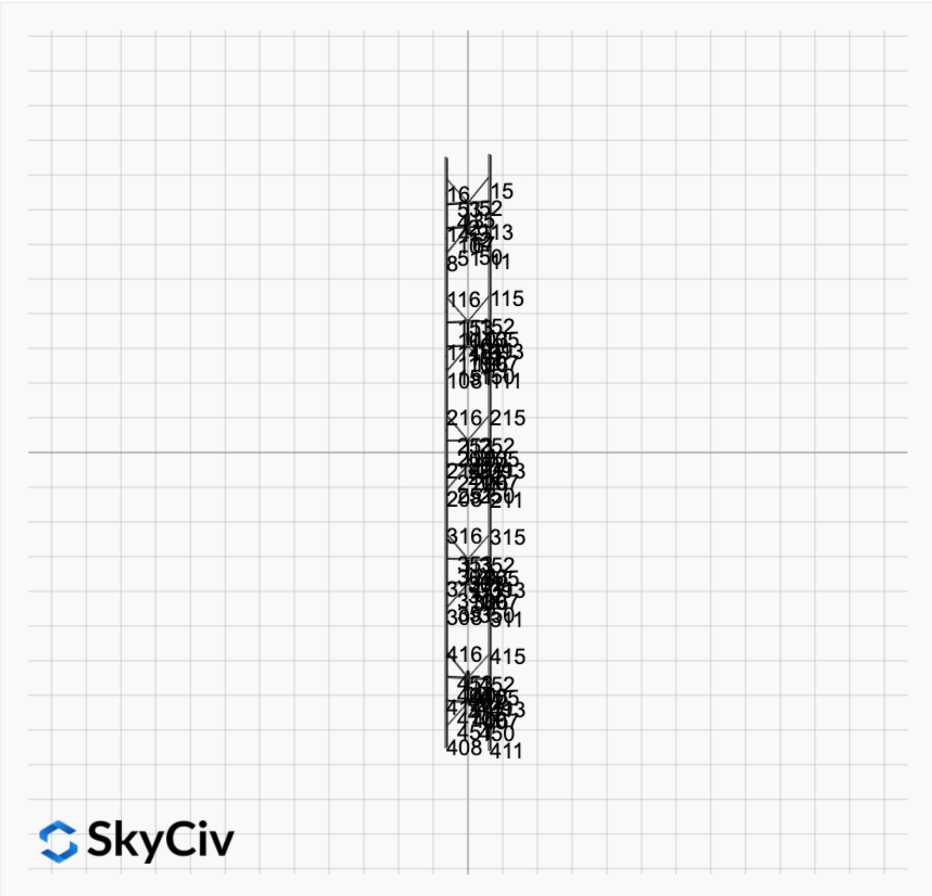
AutoDesigner Input

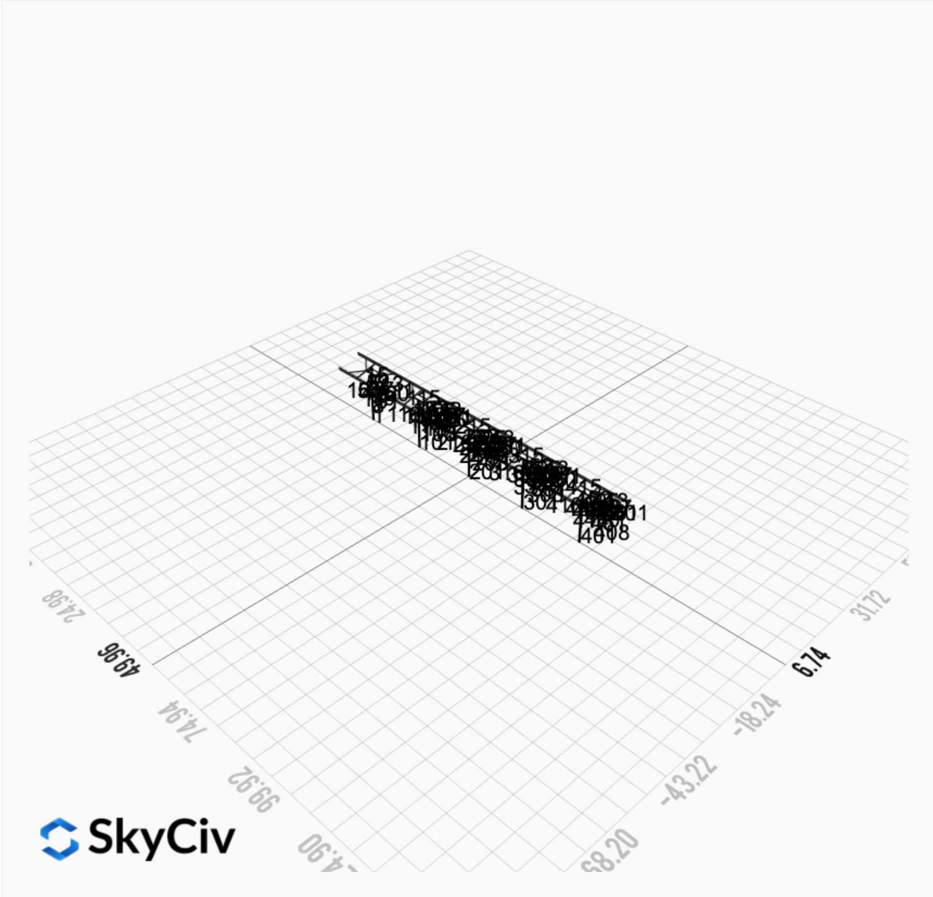
{"wind_speed_override":98,"snow_load_override":52,"direct_snow_load":false,"add_angle_brace":true,"product_type":"Beam","designer_name":"","designer_email":"","designer_phone":"","project_id":"SMPA Ridgway 375w 4x17 - 1975ft - V1Jb","site_address":"720 N Railroad St, Ridgway, CO 81432,
USA","module_width":41.34,"module_length":69.53,"number_rows":"4","number_columns":17,"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_override":19.75,"pole_spacing":"15","tilt_angle":15,"ground_clearance":14,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":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)





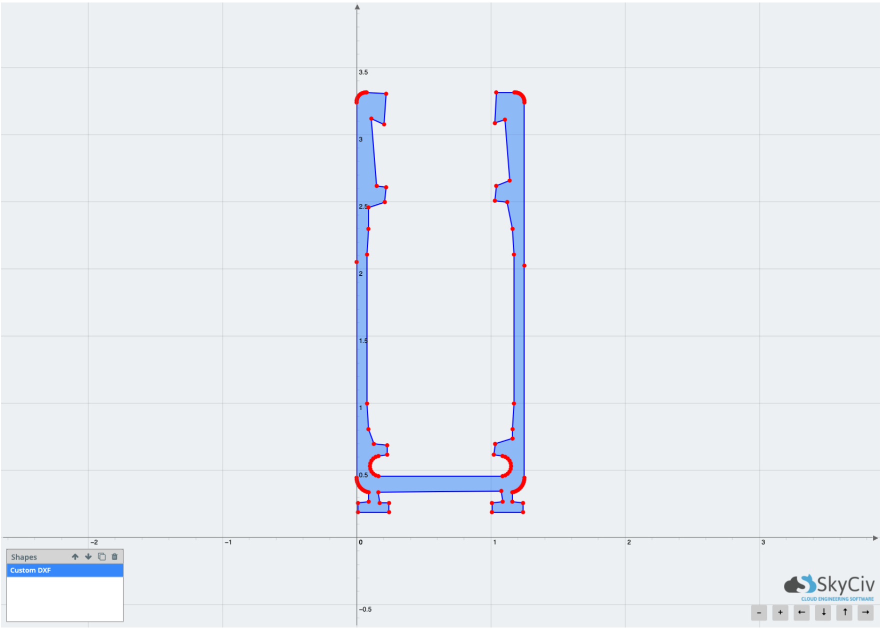


24.98
49.96
74.94
99.92
31.72
6.74
-18.24
-43.22

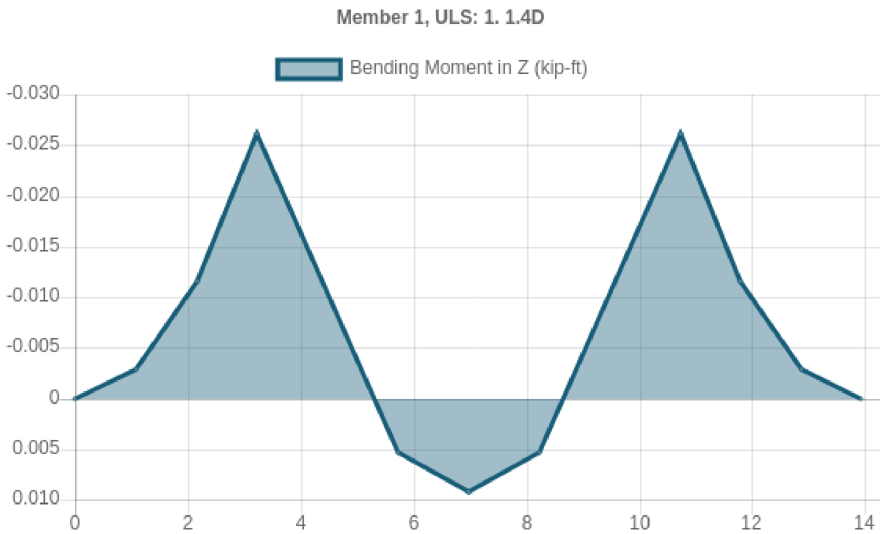
401
301
201
101
1

Rail Design Check

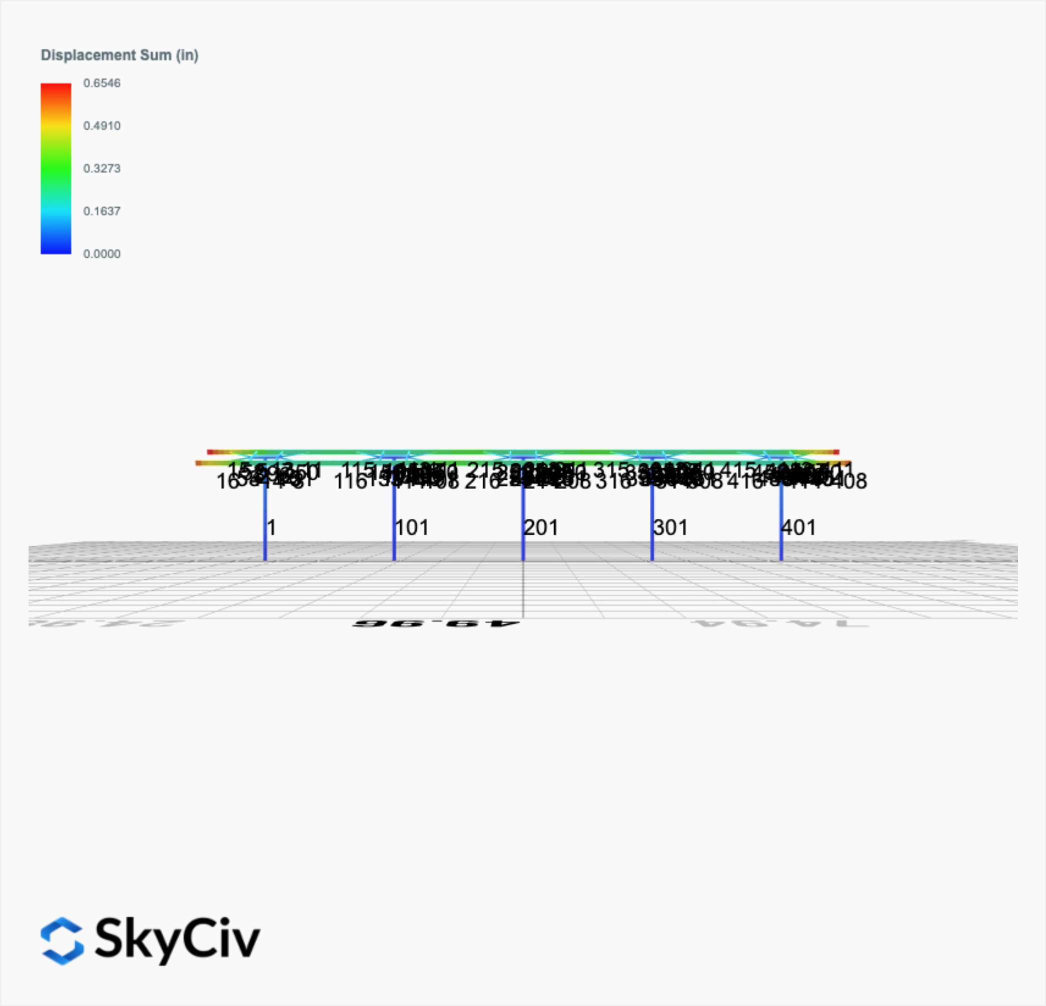
Rail Length: 13.946666666666667 ft
Additional Restraints Required: None
Tributary Width: 2.93875 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0893 kip/ft
Snow (Y): -0.0239 kip/ft
Wind uplift Case A: 0.0308 kip/ft
Wind uplift Case A: 0.0308 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0450 kip/ft

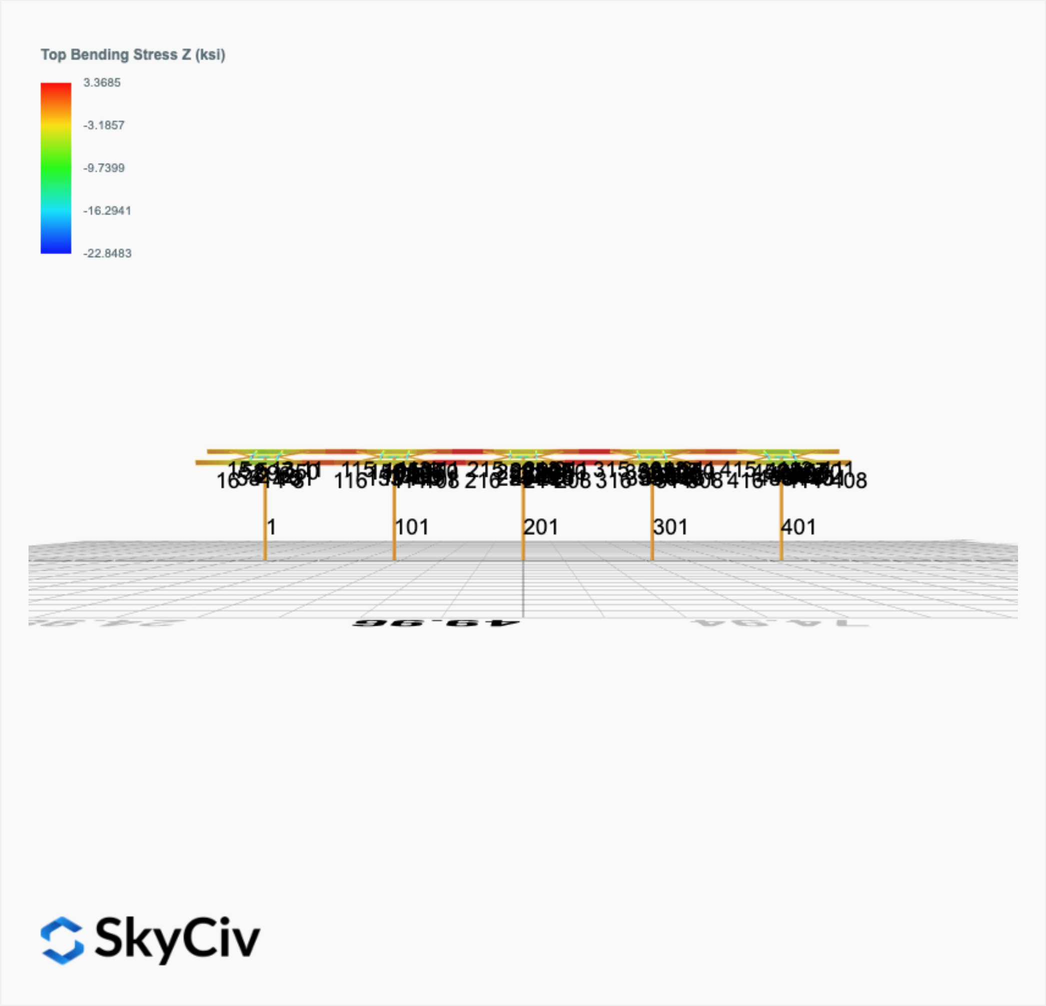


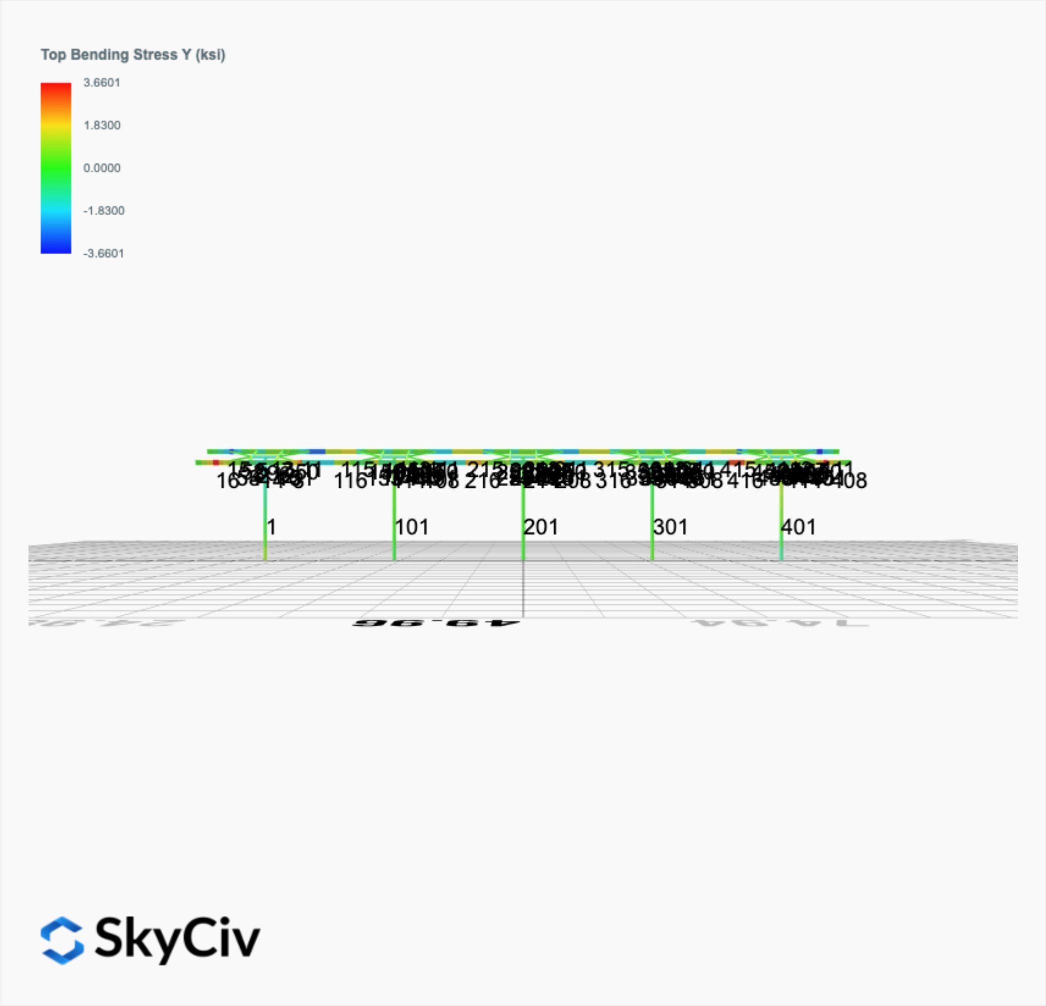
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	7.61585412	0.221	PASS
Material Yield	34.5	7.61585412	0.221	PASS
Material Strength	37	7.61585412	0.206	PASS

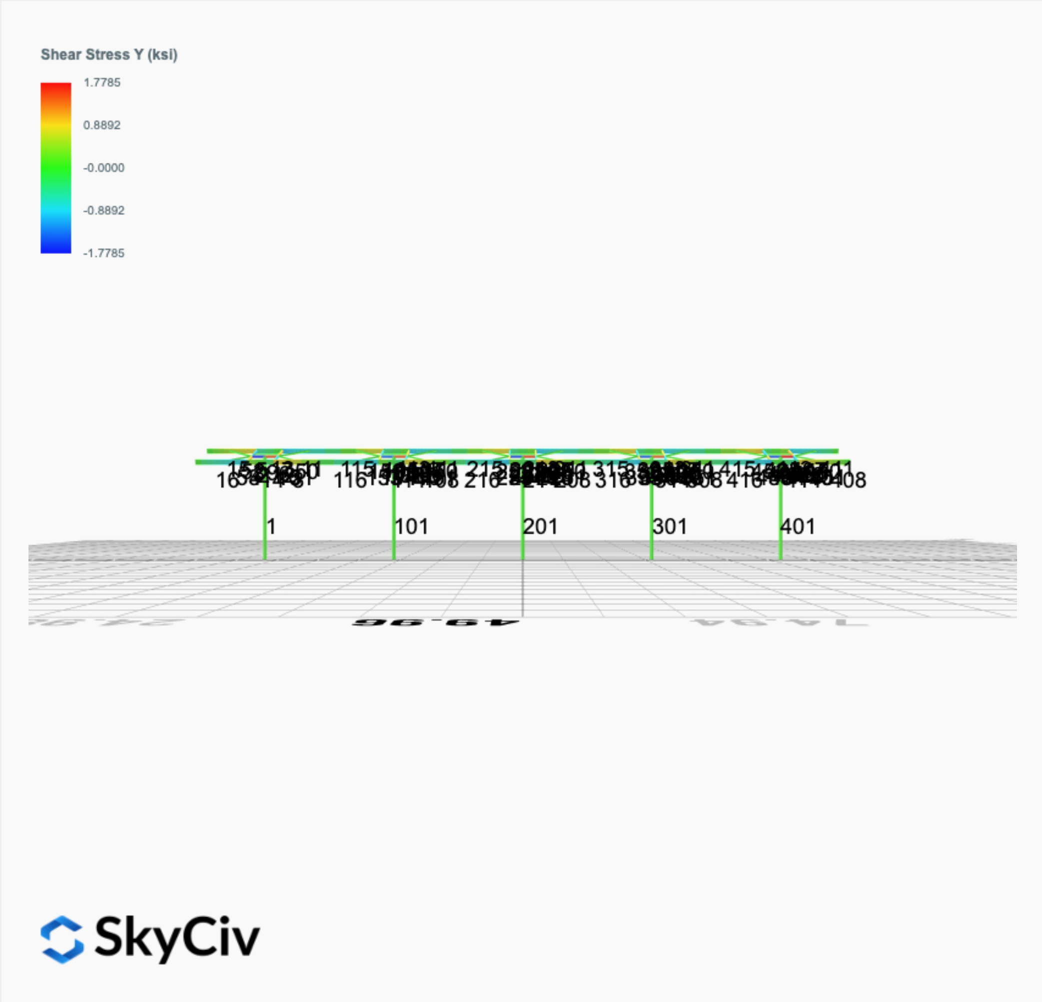


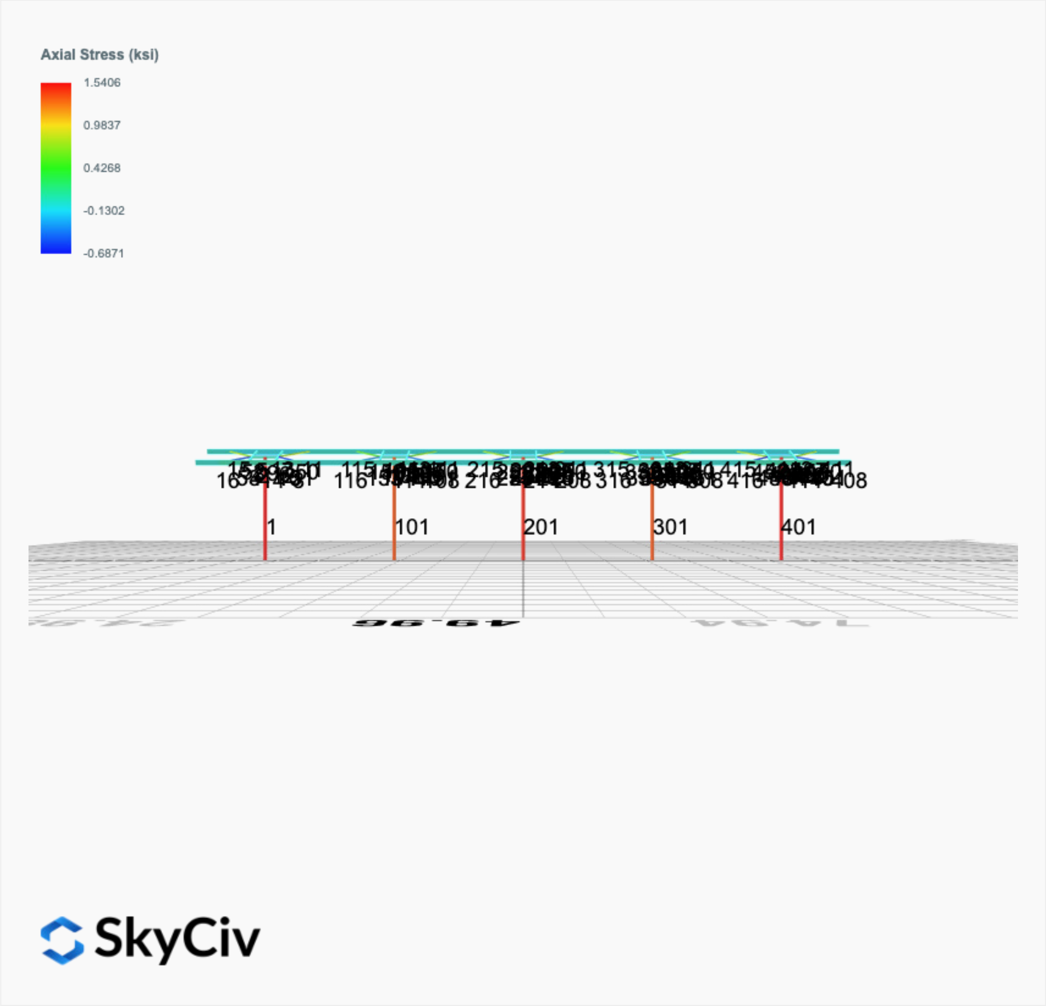
FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
3.3685
-3.1857
-9.7399
-16.2941
-22.8483
1
101
201
301
401
49.96
SkyCiv


Top Bending Stress Y (ksi)
3.6601
1.8300
0.0000
-1.8300
-3.6601
1
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
1.7785
0.8892
-0.0000
-0.8892
-1.7785
1
101
201
301
401
SkyCiv


Axial Stress (ksi)
1.5406
0.9837
0.4268
-0.1302
-0.6871
1
101
201
301
401
SkyCiv

Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0032	2.4910	-0.0218	-0.1128	0.0188	0.0747
ULS: 2. D + L	-0.0032	2.4910	-0.0218	-0.1128	0.0188	0.0747
ULS: 3. D + (S or Lr or R)	-0.0161	11.0899	-0.1203	-0.6287	0.1044	0.3152
ULS: 3. D + (S or Lr or R)	-0.0032	2.4910	-0.0218	-0.1128	0.0188	0.0747
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0129	8.9402	-0.0957	-0.4998	0.0830	0.2551
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0032	2.4910	-0.0218	-0.1128	0.0188	0.0747
ULS: 5b. D + 0.7E	-0.0032	2.4910	-0.0218	-0.1128	0.0188	0.0747
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0129	8.9402	-0.0957	-0.4998	0.0830	0.2551
ULS: 8. 0.6D + 0.7E	-0.0019	1.4946	-0.0131	-0.0677	0.0113	0.0448
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5097	4.4376	-0.0457	-0.2369	0.0406	9.3026
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5097	4.4376	-0.0457	-0.2369	0.0406	9.3026
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3844	1.0144	-0.0040	-0.0210	0.0031	-4.8573
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3240	1.2145	-0.0056	-0.0295	0.0035	-9.5983
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3927	10.4001	-0.1136	-0.5928	0.0993	7.1759
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3927	10.4001	-0.1136	-0.5928	0.0993	7.1759
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2778	7.8327	-0.0823	-0.4309	0.0712	-3.4440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2325	7.9828	-0.0836	-0.4372	0.0715	-6.9997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3830	3.9509	-0.0397	-0.2059	0.0351	6.9956
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3830	3.9509	-0.0397	-0.2059	0.0351	6.9956
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2875	1.3835	-0.0084	-0.0440	0.0070	-3.6243
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2422	1.5336	-0.0097	-0.0503	0.0073	-7.1800
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5084	3.4412	-0.0369	-0.1918	0.0330	9.2727
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5084	3.4412	-0.0369	-0.1918	0.0330	9.2727
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3857	0.0180	0.0047	0.0241	-0.0044	-4.8872
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3253	0.2181	0.0031	0.0156	-0.0041	-9.6282

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	18.3723
Shear X	-0.8499
Shear Z	-0.2057
Moment X	-1.0914
Moment Y (Twist)	0.1807
Moment Z	18.2069

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	11.0899
Shear X	-0.5097
Shear Z	-0.1203
Moment X	-0.6287
Moment Y (Twist)	0.1044
Moment Z	9.6282

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	0.0032	2.3651	0.0045	0.0233	-0.0031	-0.0039
ULS: 2. D + L	0.0032	2.3651	0.0045	0.0233	-0.0031	-0.0039
ULS: 3. D + (S or Lr or R)	0.0165	10.3963	0.0247	0.1293	-0.0168	-0.1174
ULS: 3. D + (S or Lr or R)	0.0032	2.3651	0.0045	0.0233	-0.0031	-0.0039
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0132	8.3885	0.0197	0.1028	-0.0133	-0.0890

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.3651	0.0045	0.0233	-0.0031	-0.0039
ULS: 5b. D + 0.7E	0.0032	2.3651	0.0045	0.0233	-0.0031	-0.0039
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0132	8.3885	0.0197	0.1028	-0.0133	-0.0890
ULS: 8. 0.6D + 0.7E	0.0019	1.4191	0.0027	0.0140	-0.0018	-0.0023
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5009	4.1748	0.0094	0.0489	-0.0056	9.1501
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5009	4.1748	0.0094	0.0489	-0.0056	9.1501
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3820	0.9927	0.0007	0.0035	-0.0007	-4.8634
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3377	1.1802	0.0014	0.0072	-0.0022	-9.6675
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3649	9.7457	0.0234	0.1220	-0.0153	6.7765
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3649	9.7457	0.0234	0.1220	-0.0153	6.7765
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2973	7.3592	0.0168	0.0880	-0.0115	-3.7337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2640	7.4998	0.0173	0.0907	-0.0127	-7.3368
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3749	3.7224	0.0082	0.0425	-0.0050	6.8616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3749	3.7224	0.0082	0.0425	-0.0050	6.8616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2873	1.3358	0.0016	0.0084	-0.0013	-3.6485
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2541	1.4765	0.0022	0.0112	-0.0024	-7.2516
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5021	3.2287	0.0076	0.0396	-0.0044	9.1517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5021	3.2287	0.0076	0.0396	-0.0044	9.1517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3807	0.0467	-0.0011	-0.0058	0.0006	-4.8619
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3364	0.2342	-0.0004	-0.0021	-0.0010	-9.6660

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.1939
Shear X	-0.8401
Shear Z	0.0419
Moment X	0.2223
Moment Y (Twist)	0.0266
Moment Z	18.4685

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.3963
Shear X	-0.5021
Shear Z	0.0247
Moment X	0.1293
Moment Y (Twist)	0.0168
Moment Z	9.6675

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	-0.0000	2.4626	-0.0000	0.0000	0.0000	0.0243
ULS: 2. D + L	-0.0000	2.4626	-0.0000	0.0000	0.0000	0.0243
ULS: 3. D + (S or Lr or R)	-0.0008	10.9341	-0.0000	0.0000	0.0000	0.0362
ULS: 3. D + (S or Lr or R)	-0.0000	2.4626	-0.0000	0.0000	0.0000	0.0243
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0006	8.8162	-0.0000	0.0000	0.0000	0.0332
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.4626	-0.0000	0.0000	0.0000	0.0243
ULS: 5b. D + 0.7E	-0.0000	2.4626	-0.0000	0.0000	0.0000	0.0243
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0006	8.8162	-0.0000	0.0000	0.0000	0.0332
ULS: 8. 0.6D + 0.7E	-0.0000	1.4775	-0.0000	0.0000	0.0000	0.0146
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5050	4.3777	-0.0000	0.0000	0.0000	9.2013
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5050	4.3777	-0.0000	0.0000	0.0000	9.2013
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3835	1.0088	-0.0000	0.0000	0.0000	-4.8678
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3317	1.2088	-0.0000	0.0000	0.0000	-9.6274

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3793	10.2526	-0.0000	0.0000	0.0000	6.9160
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3793	10.2526	-0.0000	0.0000	0.0000	6.9160
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2870	7.7258	-0.0000	0.0000	0.0000	-3.6358
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2482	7.8758	-0.0000	0.0000	0.0000	-7.2056
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3788	3.8989	-0.0000	0.0000	0.0000	6.9071
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3788	3.8989	-0.0000	0.0000	0.0000	6.9071
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2876	1.3722	-0.0000	0.0000	0.0000	-3.6447
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2487	1.5222	-0.0000	0.0000	0.0000	-7.2145
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5050	3.3927	-0.0000	0.0000	0.0000	9.1916
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5050	3.3927	-0.0000	0.0000	0.0000	9.1916
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3835	0.0237	-0.0000	0.0000	0.0000	-4.8775
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3317	0.2237	-0.0000	0.0000	0.0000	-9.6371

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	18.1044
Shear X	-0.8416
Shear Z	-0.0000
Moment X	0.0001
Moment Y (Twist)	0.0000
Moment Z	18.3371

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.9341
Shear X	-0.5050
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	9.6371

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	0.0032	2.3651	-0.0045	-0.0233	0.0031	-0.0039
ULS: 2. D + L	0.0032	2.3651	-0.0045	-0.0233	0.0031	-0.0039
ULS: 3. D + (S or Lr or R)	0.0165	10.3963	-0.0247	-0.1293	0.0168	-0.1174
ULS: 3. D + (S or Lr or R)	0.0032	2.3651	-0.0045	-0.0233	0.0031	-0.0039
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0132	8.3885	-0.0197	-0.1028	0.0134	-0.0890
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0032	2.3651	-0.0045	-0.0233	0.0031	-0.0039
ULS: 5b. D + 0.7E	0.0032	2.3651	-0.0045	-0.0233	0.0031	-0.0039
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0132	8.3885	-0.0197	-0.1028	0.0134	-0.0890
ULS: 8. 0.6D + 0.7E	0.0019	1.4191	-0.0027	-0.0140	0.0018	-0.0023
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5009	4.1748	-0.0094	-0.0489	0.0056	9.1501
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5009	4.1748	-0.0094	-0.0489	0.0056	9.1501
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3820	0.9927	-0.0007	-0.0035	0.0007	-4.8634
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3377	1.1802	-0.0014	-0.0072	0.0022	-9.6675
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3649	9.7457	-0.0234	-0.1220	0.0153	6.7765
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3649	9.7457	-0.0234	-0.1220	0.0153	6.7765
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2973	7.3592	-0.0168	-0.0880	0.0115	-3.7337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2640	7.4998	-0.0173	-0.0907	0.0127	-7.3368
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3749	3.7224	-0.0082	-0.0425	0.0050	6.8616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3749	3.7224	-0.0082	-0.0425	0.0050	6.8616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2873	1.3358	-0.0016	-0.0084	0.0013	-3.6485
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2541	1.4765	-0.0022	-0.0112	0.0024	-7.2516

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5021	3.2287	-0.0076	-0.0396	0.0044	9.1517
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5021	3.2287	-0.0076	-0.0396	0.0044	9.1517
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3807	0.0467	0.0011	0.0058	-0.0006	-4.8619
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3364	0.2342	0.0004	0.0021	0.0010	-9.6660

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.1939
Shear X	-0.8401
Shear Z	-0.0419
Moment X	-0.2223
Moment Y (Twist)	0.0266
Moment Z	18.4686

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.3963
Shear X	-0.5021
Shear Z	-0.0247
Moment X	-0.1293
Moment Y (Twist)	0.0168
Moment Z	9.6675

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0032	2.4910	0.0218	0.1128	-0.0188	0.0747
ULS: 2. D + L	-0.0032	2.4910	0.0218	0.1128	-0.0188	0.0747
ULS: 3. D + (S or Lr or R)	-0.0161	11.0899	0.1203	0.6287	-0.1044	0.3152
ULS: 3. D + (S or Lr or R)	-0.0032	2.4910	0.0218	0.1128	-0.0188	0.0747
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0129	8.9402	0.0957	0.4998	-0.0830	0.2551
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0032	2.4910	0.0218	0.1128	-0.0188	0.0747
ULS: 5b. D + 0.7E	-0.0032	2.4910	0.0218	0.1128	-0.0188	0.0747
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0129	8.9402	0.0957	0.4998	-0.0830	0.2551
ULS: 8. 0.6D + 0.7E	-0.0019	1.4946	0.0131	0.0677	-0.0113	0.0448
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5097	4.4376	0.0457	0.2369	-0.0406	9.3026
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5097	4.4376	0.0457	0.2369	-0.0406	9.3026
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.3844	1.0144	0.0040	0.0210	-0.0031	-4.8573
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3240	1.2145	0.0056	0.0295	-0.0035	-9.5983
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3927	10.4001	0.1136	0.5928	-0.0993	7.1759
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3927	10.4001	0.1136	0.5928	-0.0993	7.1759
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2778	7.8327	0.0823	0.4309	-0.0712	-3.4440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2325	7.9828	0.0836	0.4373	-0.0715	-6.9997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3830	3.9509	0.0397	0.2059	-0.0351	6.9956
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3830	3.9509	0.0397	0.2059	-0.0351	6.9956
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.2875	1.3835	0.0084	0.0440	-0.0070	-3.6243
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2422	1.5336	0.0097	0.0503	-0.0073	-7.1800
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5084	3.4412	0.0369	0.1918	-0.0330	9.2727
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5084	3.4412	0.0369	0.1918	-0.0330	9.2727
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.3857	0.0180	-0.0047	-0.0241	0.0044	-4.8872
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3253	0.2181	-0.0031	-0.0156	0.0041	-9.6282

Worst Case Reactions LRFD

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

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	18.3724
Shear X	-0.8498
Shear Z	0.2057
Moment X	1.0915
Moment Y (Twist)	0.1807
Moment Z	18.2063

Result	Value (kip, kip-ft)
Axial	11.0899
Shear X	-0.5097
Shear Z	0.1203
Moment X	0.6287
Moment Y (Twist)	0.1044
Moment Z	9.6282

Project Details

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

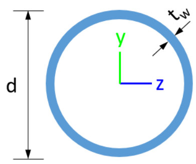
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

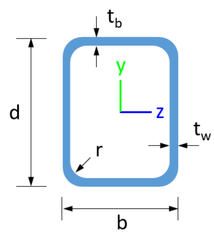
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

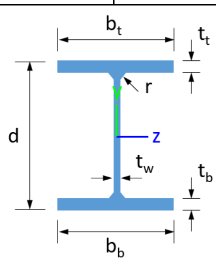
Section Dimensions



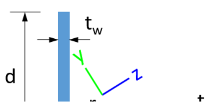
ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
7	6in Pipe Sch 40	6.63	0.28					

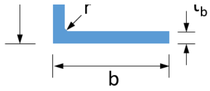


ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		



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





ID	Name	d (in)	t_w (in)	b (in)	t_b (in)	r (in)		
34	L3x2x3/16	3.00	0.19	2.00	0.19	0.31		

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60
34	L3x2x3/16	0.92	0.01	0.17	0.98	0.01	0.33	0.82

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	33.19	33.19	15.80	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.40,1.18,1.18,1.14,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.61,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.39,1.67,1.67,1.62,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.49,1.18,1.18,1.13,1.17	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.88,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.70,1.67,1.67,1.61,1.66	300	200	1
8	20	1.33	1.33	2.05	1.70,1.69,1.70,1.69,1.69,1.70,1.69,1.69,1.68,1.72,1.69,1.69,1.70,1.79,1.69,1.69,1.68,1.69,1.69,1.69,1.69,1.74,1.68,1.68,1.70,1.83	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
11	20	1.33	1.33	2.05	1.70,1.70,1.70,1.70,1.70,1.70,1.70,1.70,1.71,1.63,1.70,1.70,2.27,1.77,1.70,1.70,1.70,1.69,1.70,1.70,1.73,1.25,1.70,1.70,1.60,1.75	300	200	1
12	6	4.20	4.20	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.39,1.16,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.13	300	200	1
14	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.12,1.13,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.18	300	200	1
15	20	6.00	6.00	6.00	2.33,2.32,2.33,2.31,2.32,2.33,2.32,2.32,2.32,2.30,2.32,2.32,2.71,2.30,2.31,2.31,2.31,2.31,2.32,2.32,2.34,1.55,2.32,2.32,2.24,2.30	300	200	1
16	20	6.00	6.00	6.00	2.33,2.31,2.33,2.31,2.32,2.33,2.32,2.32,2.32,2.31,2.32,2.32,2.26,2.32,2.31,2.31,2.31,2.30,2.32,2.32,2.37,2.32,2.32,2.32,2.29,2.32	300	200	1
50	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
51	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
52	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
53	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
101	7	33.19	33.19	15.80	-	300	200	1
102	6	4.20	4.20	2.00	-	300	200	1

103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.66,1.18,1.18,1.12,1.17	300	200	1
104	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.74,1.69,1.67,1.67,1.64,1.69	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.31,1.67,1.67,1.61,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.56,1.18,1.18,1.13,1.17	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.56,1.67,1.67,1.61,1.66	300	200	1
108	20	1.33	1.33	2.05	1.90,1.91,1.90,1.91,1.90,1.90,1.89,1.89,1.85,2.06,1.88,1.88,2.06,2.09,1.90,1.90,1.90,1.94,1.89,1.89,1.76,2.06,1.88,1.88,2.05,2.11	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
111	20	1.33	1.33	2.05	2.00,2.00,1.99,2.01,2.00,1.99,2.03,2.03,2.05,1.61,2.04,2.04,2.19,2.10,2.02,2.02,2.01,1.96,2.02,2.02,2.06,1.06,2.04,2.04,1.65,2.09	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.06,1.06,1.16,1.10,1.06,1.06,1.06,1.06,1.06,1.06,1.05,2.14,1.06,1.06,1.06,1.07	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.07,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.06,1.06,1.06,1.06,1.11	300	200	1
115	20	10.20	10.20	10.20	1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.28,1.20,1.19,1.19,1.19,1.19,1.18,1.18,1.18,2.09,1.19,1.19,1.20,1.20	300	200	1
116	20	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.21,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.19	300	200	1
150	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
151	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
152	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
153	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
201	7	33.19	33.19	15.80	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.42,1.18,1.18,1.13,1.17	300	200	1
204	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.89,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.40,1.67,1.67,1.61,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.42,1.18,1.18,1.13,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.89,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.40,1.67,1.67,1.61,1.66	300	200	1
208	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.08,2.07	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
211	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.08,2.08,2.04,2.07,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.29,2.08,2.08,2.08,2.08	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.03,1.04,1.03,1.04,1.04,1.03,1.04,1.04,1.04,1.03,1.04,1.04,1.29,1.09,1.04,1.04,1.04,1.04,1.04,1.03,1.01,1.04,1.04,1.04,1.06	300	200	1
214	20	4.88	4.00	7.50	1.03,1.04,1.03,1.04,1.03,1.03,1.04,1.04,1.03,1.04,1.03,1.03,1.06,1.06,1.04,1.04,1.04,1.04,1.03,1.03,1.03,1.04,1.03,1.03,1.04,1.11	300	200	1
215	20	10.20	10.20	10.20	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.15,1.13,1.13,1.08,1.13,1.13,1.13,1.13,1.14,1.13,1.13,1.12,1.88,1.13,1.13,1.16,1.13	300	200	1
[illegible]	[illegible]	10.2	10.2	10	1.13,1.14,1.13,1.14,1.13,1.13,1.14,1.14,1.14,1.13,1.14,1.14,1.14,1.12,1.14,1.14,1.14,1.14,1.13,1.13,1.1	30	20	[illegible]

216	20	10.20	10.20	10.20	[illegible]3,1.13,1.14,1.14,1.14,1.13	300	200	1
250	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
251	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
252	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
253	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
301	7	33.19	33.19	15.80	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.56,1.18,1.18,1.13,1.17	300	200	1
304	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.56,1.67,1.67,1.61,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.29,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.66,1.18,1.18,1.12,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.32,1.67,1.67,1.61,1.66	300	200	1
308	20	1.33	1.33	2.05	2.08,2.07,2.08,2.07,2.07,2.08,2.07,2.07,2.07,2.09,2.07,2.07,2.42,2.36,2.07,2.07,2.07,2.08,2.07,2.07,2.06,2.15,2.07,2.07,2.12,2.32	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.74,1.69,1.67,1.67,1.64,1.69	300	200	1
311	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.10,2.10,1.97,2.10,2.10,2.03,2.33,2.10,2.10,2.09,2.09,2.10,2.10,2.11,1.10,2.10,2.10,2.02,2.36	300	200	1
312	6	4.20	4.20	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.06,1.06,1.16,1.10,1.06,1.06,1.06,1.06,1.06,1.06,1.05,2.15,1.06,1.06,1.06,1.07	300	200	1
314	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.07,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.06,1.06,1.06,1.06,1.11	300	200	1
315	20	10.20	10.20	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.18,1.14,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.57,1.12,1.12,1.12,1.13	300	200	1
316	20	10.20	10.20	10.20	1.11,1.12,1.11,1.12,1.12,1.11,1.12,1.12,1.11,1.12,1.12,1.12,1.13,1.13,1.12,1.12,1.12,1.12,1.11,1.11,1.10,1.12,1.12,1.12,1.13,1.14	300	200	1
350	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
351	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
352	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
353	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
401	7	33.19	33.19	15.80	-	300	200	1
402	6	4.20	4.20	2.00	-	300	200	1
403	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.49,1.18,1.18,1.13,1.17	300	200	1
404	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
405	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.88,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.70,1.67,1.67,1.61,1.66	300	200	1
406	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.30,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.40,1.18,1.18,1.14,1.17	300	200	1
407	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.87,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.39,1.67,1.67,1.62,1.66	300	200	1
408	20	6.00	6.00	6.00	2.33,2.31,2.33,2.31,2.32,2.33,2.32,2.32,2.32,2.31,2.32,2.32,2.26,2.32,2.31,2.31,2.31,2.30,2.32,2.32,2.37,2.32,2.32,2.32,2.29,2.32	300	200	1
409	3	2.60	2.60	4.00	-	300	200	1

410	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.61,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69	300	200	1
411	20	6.00	6.00	6.00	2.33,2.32,2.33,2.31,2.32,2.33,2.32,2.32,2.32,2.30,2.32,2.32,2.71,2.30,2.31,2.31,2.31,2.31,2.32,2.32,2.34,1.55,2.32,2.32,2.24,2.30	300	200	1
412	6	1.30	1.30	2.00	-	300	200	1
413	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.39,1.16,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.13	300	200	1
414	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.12,1.13,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.18	300	200	1
415	20	10.20	10.20	10.20	1.52,1.53,1.52,1.53,1.52,1.52,1.52,1.52,1.51,1.63,1.52,1.52,1.10,1.43,1.53,1.53,1.53,1.54,1.52,1.52,1.48,2.70,1.52,1.52,1.69,1.45	300	200	1
416	20	10.20	10.20	10.20	1.52,1.53,1.52,1.53,1.52,1.52,1.54,1.54,1.54,1.48,1.54,1.54,1.50,1.40,1.54,1.54,1.53,1.52,1.53,1.53,1.53,1.46,1.54,1.54,1.51,1.36	300	200	1
450	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
451	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
452	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
453	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250

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	251.16	40.08	42.30	42.30	75.35	75.35
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	229.64	27.16	27.16	75.30	75.30
13	159.30	97.43	32.34	6.46	56.26	44.91
14	159.30	97.43	32.56	6.46	56.26	44.91
15	159.30	86.08	46.90	6.46	56.26	44.91
16	159.30	86.08	46.90	6.46	56.26	44.91
50	41.27	8.45	1.63	0.88	15.23	10.15
51	41.27	8.45	1.63	0.88	15.23	10.15
52	41.27	8.45	1.63	0.88	15.23	10.15
53	41.27	8.45	1.63	0.88	15.23	10.15
101	251.16	40.08	42.30	42.30	75.35	75.35
102	251.01	229.64	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95

111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	32.18	6.46	56.26	44.91
114	159.30	97.43	32.11	6.46	56.26	44.91
115	159.30	32.87	22.69	6.46	56.26	44.91
116	159.30	32.87	22.44	6.46	56.26	44.91
150	41.27	8.45	1.63	0.88	15.23	10.15
151	41.27	8.45	1.63	0.88	15.23	10.15
152	41.27	8.45	1.63	0.88	15.23	10.15
153	41.27	8.45	1.63	0.88	15.23	10.15
201	251.16	40.08	42.30	42.30	75.35	75.35
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	30.90	6.46	56.26	44.91
214	159.30	97.43	31.47	6.46	56.26	44.91
215	159.30	32.87	20.80	6.46	56.26	44.91
216	159.30	32.87	21.63	6.46	56.26	44.91
250	41.27	8.45	1.63	0.88	15.23	10.15
251	41.27	8.45	1.63	0.88	15.23	10.15
252	41.27	8.45	1.63	0.88	15.23	10.15
253	41.27	8.45	1.63	0.88	15.23	10.15
301	251.16	40.08	42.30	42.30	75.35	75.35
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	140.46	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	140.46	46.90	6.46	56.26	44.91
312	251.01	229.64	27.16	27.16	75.30	75.30
313	159.30	97.43	32.20	6.46	56.26	44.91
314	159.30	97.43	32.11	6.46	56.26	44.91
315	159.30	32.87	21.40	6.46	56.26	44.91
316	159.30	32.87	21.26	6.46	56.26	44.91
350	41.27	8.45	1.63	0.88	15.23	10.15
351	41.27	8.45	1.63	0.88	15.23	10.15
352	41.27	8.45	1.63	0.88	15.23	10.15
353	41.27	8.45	1.63	0.88	15.23	10.15
401	251.16	40.08	42.30	42.30	75.35	75.35

402	251.01	229.64	27.16	27.16	75.30	75.30
403	151.65	150.70	20.17	14.14	54.12	28.95
404	151.65	145.15	20.17	14.14	54.12	28.95
405	151.65	149.10	20.17	14.14	54.12	28.95
406	151.65	150.70	20.17	14.14	54.12	28.95
407	151.65	149.10	20.17	14.14	54.12	28.95
408	159.30	86.08	46.90	6.46	56.26	44.91
409	75.10	66.32	4.25	4.25	22.53	22.53
410	151.65	145.15	20.17	14.14	54.12	28.95
411	159.30	86.08	46.90	6.46	56.26	44.91
412	251.01	248.88	27.16	27.16	75.30	75.30
413	159.30	97.43	32.42	6.46	56.26	44.91
414	159.30	97.43	32.55	6.46	56.26	44.91
415	159.30	32.87	21.21	6.46	56.26	44.91
416	159.30	32.87	26.15	6.46	56.26	44.91
450	41.27	8.45	1.63	0.88	15.23	10.15
451	41.27	8.45	1.63	0.88	15.23	10.15
452	41.27	8.45	1.63	0.88	15.23	10.15
453	41.27	8.45	1.63	0.88	15.23	10.15

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	0.458	0.430	0.051	0.011	0.003	0.711	#21	0.887	Not Required	Pass
2	0.004	0.619	0.054	0.125	0.006	0.675	#21	0.054	Not Required	Pass
3	0.002	0.852	0.080	0.086	0.032	0.933	#21	0.046	Not Required	Pass
4	0.002	0.830	0.015	0.083	0.001	0.844	#21	0.082	Not Required	Pass
5	0.002	0.528	0.014	0.085	0.005	0.544	#21	0.076	Not Required	Pass
6	0.002	0.778	0.077	0.077	0.032	0.856	#21	0.046	Not Required	Pass
7	0.002	0.483	0.016	0.077	0.005	0.500	#21	0.076	Not Required	Pass
8	0.005	0.113	0.074	0.051	0.007	0.123	#21	0.102	Not Required	Pass
9	0.015	0.107	0.028	0.002	0.000	0.142	#21	0.137	Not Required	Pass
10	0.002	0.762	0.042	0.076	0.006	0.805	#21	0.122	Not Required	Pass
11	0.005	0.113	0.068	0.052	0.007	0.117	#21	0.068	Not Required	Pass
12	0.003	0.540	0.048	0.114	0.005	0.589	#21	0.174	Not Required	Pass
13	0.005	0.410	0.021	0.065	0.005	0.434	#21	0.204	Not Required	Pass
14	0.008	0.409	0.033	0.064	0.006	0.446	#21	0.306	Not Required	Pass
15	0.005	0.165	0.097	0.046	0.008	0.170	#21	0.306	Not Required	Pass
16	0.009	0.161	0.097	0.045	0.008	0.175	#21	0.306	Not Required	Pass
50	0.143	0.010	0.004	0.002	0.001	0.155	#21	0.783	Not Required	Pass
51	0.029	0.009	0.011	0.002	0.002	0.045	#21	0.522	Not Required	Pass
52	0.131	0.010	0.004	0.002	0.001	0.143	#24	0.783	Not Required	Pass
53	0.026	0.009	0.011	0.002	0.002	0.042	#24	0.522	Not Required	Pass
101	0.429	0.437	0.010	0.011	0.001	0.648	#21	0.887	Not Required	Pass
102	0.003	0.524	0.045	0.111	0.006	0.570	#21	0.174	Not Required	Pass
103	0.003	0.757	0.070	0.076	0.029	0.827	#21	0.046	Not Required	Pass
104	0.003	0.732	0.031	0.073	0.005	0.765	#21	0.082	Not Required	Pass
105	0.003	0.470	0.013	0.075	0.003	0.484	#21	0.076	Not Required	Pass
106	0.002	0.771	0.073	0.077	0.029	0.845	#21	0.046	Not Required	Pass
107	0.002	0.478	0.010	0.076	0.003	0.488	#21	0.076	Not Required	Pass
108	0.003	0.070	0.033	0.045	0.005	0.102	#21	0.102	Not Required	Pass

109	0.012	0.077	0.025	0.001	0.000	0.109	#21	0.137	Not Required	Pass
110	0.003	0.748	0.028	0.075	0.004	0.778	#21	0.082	Not Required	Pass
111	0.004	0.068	0.034	0.046	0.005	0.102	#21	0.068	Not Required	Pass
112	0.003	0.540	0.046	0.113	0.006	0.587	#21	0.054	Not Required	Pass
113	0.004	0.232	0.028	0.059	0.005	0.262	#21	0.204	Not Required	Pass
114	0.005	0.223	0.036	0.058	0.005	0.242	#21	0.306	Not Required	Pass
115	0.005	0.195	0.092	0.042	0.010	0.244	#21	0.520	Not Required	Pass
116	0.020	0.196	0.097	0.040	0.010	0.245	#21	0.780	Not Required	Pass
150	0.114	0.010	0.004	0.002	0.001	0.127	#24	0.783	Not Required	Pass
151	0.023	0.009	0.011	0.002	0.001	0.039	#23	0.522	Not Required	Pass
152	0.100	0.010	0.004	0.002	0.001	0.112	#24	0.783	Not Required	Pass
153	0.019	0.009	0.011	0.002	0.001	0.036	#24	0.522	Not Required	Pass
201	0.452	0.434	0.000	0.011	0.000	0.671	#21	0.887	Not Required	Pass
202	0.003	0.561	0.048	0.118	0.006	0.611	#21	0.054	Not Required	Pass
203	0.002	0.802	0.076	0.080	0.031	0.879	#21	0.046	Not Required	Pass
204	0.002	0.784	0.029	0.078	0.004	0.815	#21	0.082	Not Required	Pass
205	0.002	0.498	0.013	0.080	0.004	0.512	#21	0.076	Not Required	Pass
206	0.002	0.802	0.076	0.080	0.031	0.879	#21	0.046	Not Required	Pass
207	0.002	0.498	0.013	0.080	0.004	0.512	#21	0.076	Not Required	Pass
208	0.003	0.060	0.046	0.047	0.005	0.107	#21	0.102	Not Required	Pass
209	0.013	0.080	0.024	0.001	0.000	0.111	#21	0.137	Not Required	Pass
210	0.002	0.784	0.029	0.078	0.004	0.815	#21	0.082	Not Required	Pass
211	0.004	0.060	0.045	0.048	0.006	0.107	#21	0.068	Not Required	Pass
212	0.003	0.561	0.048	0.118	0.006	0.611	#21	0.054	Not Required	Pass
213	0.004	0.251	0.021	0.061	0.005	0.273	#21	0.204	Not Required	Pass
214	0.006	0.250	0.019	0.060	0.005	0.266	#21	0.306	Not Required	Pass
215	0.007	0.289	0.064	0.048	0.009	0.330	#21	0.520	Not Required	Pass
216	0.014	0.287	0.064	0.047	0.009	0.328	#21	0.780	Not Required	Pass
250	0.123	0.010	0.004	0.002	0.001	0.136	#21	0.783	Not Required	Pass
251	0.025	0.009	0.011	0.002	0.002	0.041	#21	0.522	Not Required	Pass
252	0.123	0.010	0.004	0.002	0.001	0.136	#21	0.783	Not Required	Pass
253	0.025	0.009	0.011	0.002	0.002	0.041	#21	0.522	Not Required	Pass
301	0.429	0.437	0.010	0.011	0.001	0.648	#21	0.887	Not Required	Pass
302	0.003	0.540	0.046	0.113	0.006	0.587	#21	0.054	Not Required	Pass
303	0.002	0.771	0.073	0.077	0.029	0.845	#21	0.046	Not Required	Pass
304	0.003	0.748	0.028	0.075	0.004	0.778	#21	0.082	Not Required	Pass
305	0.002	0.478	0.010	0.076	0.003	0.488	#21	0.076	Not Required	Pass
306	0.003	0.757	0.070	0.076	0.029	0.827	#21	0.046	Not Required	Pass
307	0.003	0.470	0.013	0.075	0.003	0.484	#21	0.076	Not Required	Pass
308	0.003	0.046	0.014	0.040	0.004	0.056	#24	0.102	Not Required	Pass
309	0.012	0.077	0.025	0.001	0.000	0.109	#21	0.137	Not Required	Pass
310	0.003	0.732	0.031	0.073	0.005	0.765	#21	0.082	Not Required	Pass
311	0.004	0.043	0.017	0.042	0.004	0.054	#21	0.068	Not Required	Pass
312	0.003	0.524	0.045	0.111	0.006	0.570	#21	0.174	Not Required	Pass
313	0.004	0.232	0.028	0.059	0.005	0.262	#21	0.204	Not Required	Pass
314	0.005	0.223	0.036	0.058	0.005	0.242	#21	0.306	Not Required	Pass
315	0.007	0.293	0.064	0.046	0.009	0.333	#21	0.520	Not Required	Pass
316	0.014	0.292	0.064	0.045	0.009	0.333	#21	0.780	Not Required	Pass
350	0.100	0.010	0.004	0.002	0.001	0.112	#24	0.783	Not Required	Pass
351	0.019	0.009	0.011	0.002	0.001	0.036	#24	0.522	Not Required	Pass
352	0.114	0.010	0.004	0.002	0.001	0.127	#24	0.783	Not Required	Pass
353	0.023	0.009	0.011	0.002	0.001	0.039	#23	0.522	Not Required	Pass

401	0.458	0.430	0.051	0.011	0.003	0.711	#21	0.887	Not Required	Pass
402	0.003	0.540	0.048	0.114	0.005	0.589	#21	0.174	Not Required	Pass
403	0.002	0.778	0.077	0.077	0.032	0.856	#21	0.046	Not Required	Pass
404	0.002	0.762	0.042	0.076	0.006	0.805	#21	0.082	Not Required	Pass
405	0.002	0.483	0.016	0.077	0.005	0.500	#21	0.076	Not Required	Pass
406	0.002	0.852	0.080	0.086	0.032	0.933	#21	0.046	Not Required	Pass
407	0.002	0.528	0.014	0.085	0.005	0.544	#21	0.076	Not Required	Pass
408	0.009	0.161	0.097	0.045	0.008	0.175	#21	0.459	Not Required	Pass
409	0.015	0.107	0.028	0.002	0.000	0.142	#21	0.137	Not Required	Pass
410	0.002	0.830	0.015	0.083	0.001	0.844	#21	0.082	Not Required	Pass
411	0.005	0.165	0.097	0.046	0.008	0.170	#21	0.306	Not Required	Pass
412	0.004	0.619	0.054	0.125	0.006	0.675	#21	0.054	Not Required	Pass
413	0.005	0.410	0.021	0.065	0.005	0.434	#21	0.204	Not Required	Pass
414	0.008	0.409	0.033	0.064	0.006	0.446	#21	0.306	Not Required	Pass
415	0.005	0.180	0.092	0.052	0.010	0.200	#21	0.520	Not Required	Pass
416	0.020	0.179	0.097	0.051	0.010	0.200	#21	0.780	Not Required	Pass
450	0.131	0.010	0.004	0.002	0.001	0.143	#23	0.783	Not Required	Pass
451	0.026	0.009	0.011	0.002	0.002	0.042	#24	0.522	Not Required	Pass
452	0.143	0.010	0.004	0.002	0.001	0.155	#21	0.783	Not Required	Pass
453	0.029	0.009	0.011	0.002	0.002	0.045	#21	0.522	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

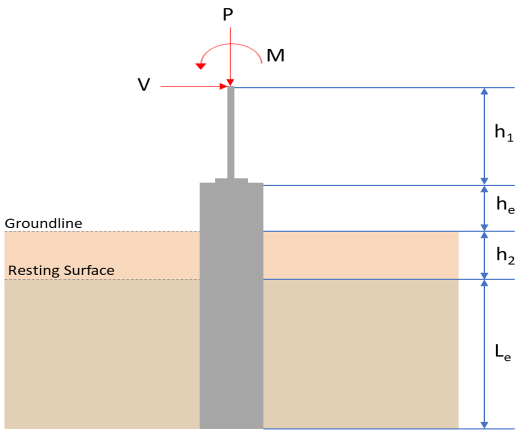
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.090	18.372
V_x (kip)	-0.510	-0.850
V_z (kip)	-0.120	-0.206
M_x (kipft)	-0.629	-1.091
M_z (kipft)	9.628	18.207

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.51 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.08121 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.628\ \text{kipft}) + ((-0.51\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.5331\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.6421\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.12\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.019108\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.629\ \text{kipft}) + ((-0.12\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.10016\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.8107\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.6421\ \text{ft}), (1.8107\ \text{ft})]$$

$$L_{e,req} = 4.642\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.642\ \text{ft})}{(5\ \text{ft})}$$

$$Ratio = 0.9284$$

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

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

$$q = \frac{(11.09\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.69313\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.69313\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.34656$$

Status: **PASS**
Ratio: **0.350**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.08121\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5331\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5331\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.08121\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (1.5331\ \mathrm{kipft/ft})) + (4 \times (-0.08121\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3959\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5331\ \mathrm{kipft/ft})) + (3 \times (-0.08121\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^2}{(5\ \mathrm{ft})^2 \times [(3 \times (1.5331\ \mathrm{kipft/ft})) + (2 \times (-0.08121\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.1913\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5331\ \mathrm{kipft/ft})) + ((-0.08121\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.63845\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.3959\ \mathrm{ft})}{2}$$

$$p_a = 0.25469\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1913\ \mathrm{kip/ft^2}\right)}{\left(0.25469\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75113$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.63845\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85126$$

Status: **PASS**
Ratio: **0.850**

Considering z-direction:

$H_o = -0.019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10016\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10016\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.10016\ \mathrm{kipft/ft})) + (4 \times (-0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4953\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.10016\ \mathrm{kipft/ft})) + (3 \times (-0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^{\ 2}}{(5\ \mathrm{ft})^2 \times [(3 \times (0.10016\ \mathrm{kipft/ft})) + (2 \times (-0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.0035648\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.10016\ \mathrm{kipft/ft})) + ((-0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.025146\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.4953\ \mathrm{ft})}{2}$$

$$p_a = 0.26215\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0035648\ \mathrm{kip/ft^2}\right)}{\left(0.26215\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.013598$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

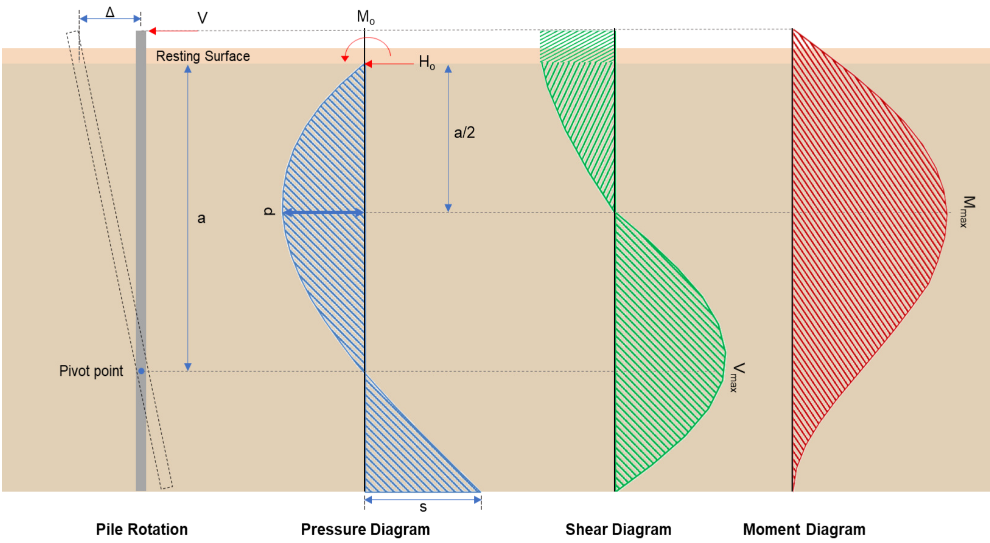
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.025146\ \mathrm{kip/ft^2})}{(0.75\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.033529$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.85\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.13535\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.207\ \mathrm{kipft}) + ((-0.85\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.8992\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.8992\ \mathrm{kipft/ft})}{(-0.13535\ \mathrm{kip/ft})}$$

$$E = 21.42\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.8992\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.13535\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (2.8992\ \mathrm{kipft/ft})) + (4 \times (-0.13535\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3894\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.13535\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.42\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.42\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4683\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.13535\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5\ \mathrm{ft})) \times \left[\left(\frac{(21.42\ \mathrm{ft})}{(5\ \mathrm{ft})} + \frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.42\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.42\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 10.922\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.206\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.032803\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.091\ \mathrm{kipft}) + ((-0.206\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.17373\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17373\ \mathrm{kipft/ft})}{(-0.032803\ \mathrm{kip/ft})}$$

$$E = 5.2961\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17373\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.032803\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.17373\ \mathrm{kipft/ft})) + (4 \times (-0.032803\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4943\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.032803\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.2961\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.4943\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.2961\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.4943\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33255\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.032803\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5\ \mathrm{ft})) \times \left[\left(\frac{(5.2961\ \mathrm{ft})}{(5\ \mathrm{ft})} + \frac{(3.4943\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (5.2961\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.4943\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.2961\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.4943\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.77222\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.372\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -83.986\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.986\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	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 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), Min\left(D, b\right)\right]$$ $$s_{ties} = Min\left[\left(16 \times (0.625\ \text{in})\right), \left(48 \times (0.375\ \text{in})\right), Min\left((48\ \text{in}), (48\ \text{in})\right)\right]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(18.372\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0068676$$	Status: **PASS** Ratio: **0.010**
22.5.2.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ 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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 18.372 \text{ kip} \rightarrow 18372 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18372 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.93 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.93 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.93 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.69 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.4683 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(4.4683\ \text{kip})}{(111.69\ \text{kip})}$$ $$Ratio = 0.040006$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $V_{max} = 0.33255\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.33255\ \text{kip})}{(111.69\ \text{kip})}$$ $$Ratio = 0.0029775$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 10.922\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.922\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.04376$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.77222\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.77222 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0030938$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

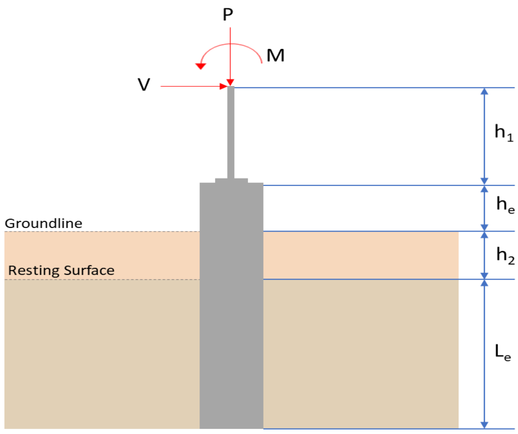
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.396	17.194
V_x (kip)	-0.502	-0.840
V_z (kip)	0.025	0.042
M_x (kipft)	0.129	0.222
M_z (kipft)	9.668	18.469

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.502\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.079936\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.668 \text{ kipft}) + ((-0.502 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.5395 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.6545 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.025 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0039809 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.129 \text{ kipft}) + ((0.025 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.020541 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.2474 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.6545 \text{ ft}), (1.2474 \text{ ft})]$$

$$L_{e,req} = 4.654 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.654 \text{ ft})}{(5 \text{ ft})}$$

$$Ratio = 0.9308$$

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

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

$$q = \frac{(10.396\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.64975\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.64975\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.32488$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.079936\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5395\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5395\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (1.5395\ \mathrm{kipft/ft})) + (4 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3948\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5395\ \mathrm{kipft/ft})) + (3 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^2}{(5\ \mathrm{ft})^2 \times [(3 \times (1.5395\ \mathrm{kipft/ft})) + (2 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.19317\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5395\ \mathrm{kipft/ft})) + ((-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.64303\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.3948\ \mathrm{ft})}{2}$$

$$p_a = 0.25461\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.19317\ \mathrm{kip/ft^2}\right)}{\left(0.25461\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75868$$

Status: **PASS**
Ratio: **0.760**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.64303\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85738$$

Status: **PASS**
Ratio: **0.860**

Considering z-direction:

$H_o = 0.0039809\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.020541\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.020541\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.020541\ \mathrm{kipft/ft})) + (4 \times (0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4969\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.020541\ \mathrm{kipft/ft})) + (3 \times (0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^{\ 2}}{(5\ \mathrm{ft})^2 \times [(3 \times (0.020541\ \mathrm{kipft/ft})) + (2 \times (0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.0059536\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.020541\ \mathrm{kipft/ft})) + ((0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.014637\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.4969\ \mathrm{ft})}{2}$$

$$p_a = 0.26226\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0059536\ \mathrm{kip/ft^2}\right)}{\left(0.26226\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.022701$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

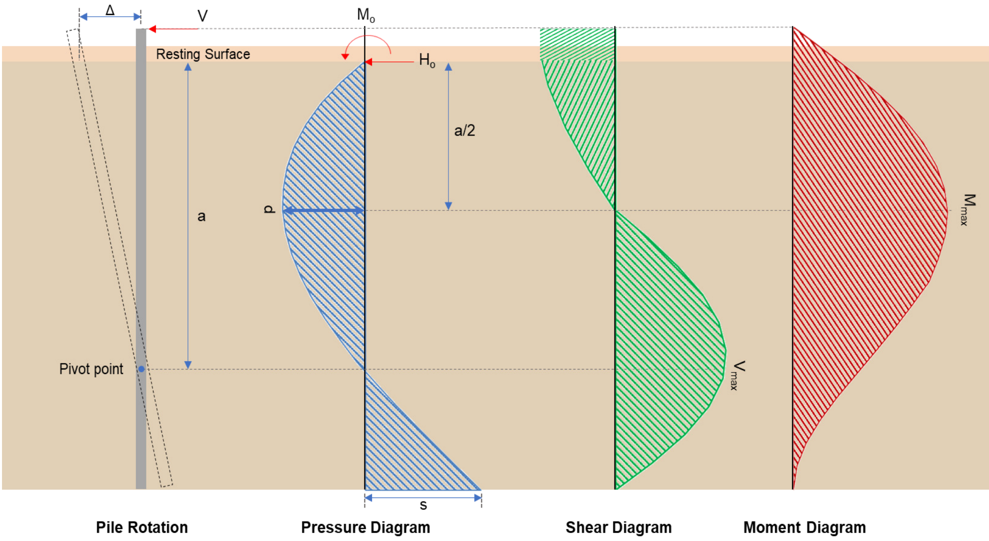
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.014637\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.019516$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.84\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.13376\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.469\ \mathrm{kipft}) + ((-0.84\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.9409\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.9409\ \mathrm{kipft/ft})}{(-0.13376\ \mathrm{kip/ft})}$$

$$E = 21.987\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.9409\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.13376\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (2.9409\ \mathrm{kipft/ft})) + (4 \times (-0.13376\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3882\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.13376\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.5235\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.13376\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5\ \mathrm{ft})) \times \left[\left(\frac{(21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + \frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 11.063\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.042\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0066879\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.222\ \mathrm{kipft}) + ((0.042\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.03535\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.03535\ \mathrm{kipft/ft})}{(0.0066879\ \mathrm{kip/ft})}$$

$$E = 5.2857\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.03535\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (0.0066879\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.03535\ \mathrm{kipft/ft})) + (4 \times (0.0066879\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4945\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0066879\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.2857\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.4945\ \text{ft})}{(5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.2857\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.4945\ \text{ft})}{(5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.067704\ \text{kip}$$

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

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

$$M_{max} = ((0.0066879\ \text{kip/ft}) \times (48\ \text{in}) \times (5\ \text{ft})) \times \left[\left(\frac{(5.2857\ \text{ft})}{(5\ \text{ft})} + \frac{(3.4945\ \text{ft})}{2 \times (5\ \text{ft})}\right) - \left[\left(\frac{4 \times (5.2857\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.4945\ \text{ft})}{2 \times (5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.2857\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.4945\ \text{ft})}{2 \times (5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.1572\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.194\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.025\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.025\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.194 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0064272$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.194 \text{ kip} \rightarrow 17194 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17194 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.78 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.78 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.78 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.78 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.59 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.5235 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(4.5235\ \mathrm{kip})}{(111.59\ \mathrm{kip})}$$ $$Ratio = 0.040538$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $V_{max} = 0.067704\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.067704\ \mathrm{kip})}{(111.59\ \mathrm{kip})}$$ $$Ratio = 0.00060674$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 11.063\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(11.063\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.044324$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.1572\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.1572 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0006298$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

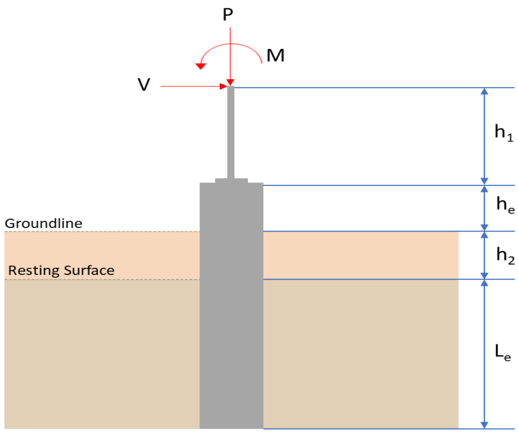
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.934	18.104
V_x (kip)	-0.505	-0.842
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	9.637	18.337

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.505\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.080414\ \mathrm{kip/ft}$$

	M_o - Moment per length of pile, $$M_o = \frac{M_z + (V_x\,H)}{1.57\,D}$$ $$M_o = \frac{(9.637\ \mathrm{kipft}) + ((-0.505\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$ $$M_o = 1.5346\ \mathrm{kipft/ft}$$ Required depth of embedment in earth: $$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$ Solving the cubic equation: $L_{e,x} = 4.6469\ \mathrm{ft}$ - Required depth in x-direction, **Considering z-direction:** $L_{e,z} = 0\ \mathrm{ft}$ - Required depth in z-direction, **Minimum embedded depth required:** $L_{e,req}$ - Depth of pile required, $$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$ $$L_{e,req} = MAX[(4.6469\ \mathrm{ft}), (0\ \mathrm{ft})]$$ $$L_{e,req} = 4.647\ \mathrm{ft}$$ L_e - Actual embedded length of pile, $$L_e = L - h_e - h_2$$ $$L_e = (5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$ $$L_e = 5\ \mathrm{ft}$$ $Ratio$ - Embedded depth $$Ratio = \frac{L_{e,req}}{L_e}$$ $$Ratio = \frac{(4.647\ \mathrm{ft})}{(5\ \mathrm{ft})}$$ $$Ratio = 0.9294$$	Status: **PASS** Ratio: **0.930**
	End-bearing Capacity (ASD) A - Pile cross-section area $$A = b\,D$$ $$A = (48\ \mathrm{in}) \times (48\ \mathrm{in})$$ $$A = 16\ \mathrm{ft}^2$$ q - End-bearing pressure $$q = \frac{P_v}{A}$$ $$q = \frac{(10.934\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$ $$q = 0.68338\ \mathrm{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{\left(0.68338\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$ $$Ratio = 0.34169$$	Status: **PASS** Ratio: **0.340**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio,	

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

$$L/D = \frac{(5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.080414\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5346\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5346\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.080414\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (1.5346\ \mathrm{kipft/ft})) + (4 \times (-0.080414\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3953\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5346\ \mathrm{kipft/ft})) + (3 \times (-0.080414\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^2}{(5\ \mathrm{ft})^2 \times [(3 \times (1.5346\ \mathrm{kipft/ft})) + (2 \times (-0.080414\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.19206\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5346\ \mathrm{kipft/ft})) + ((-0.080414\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.64009\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.3953\ \mathrm{ft})}{2}$$

$$p_a = 0.25465\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.19206\ \mathrm{kip/ft^2}\right)}{\left(0.25465\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75423$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

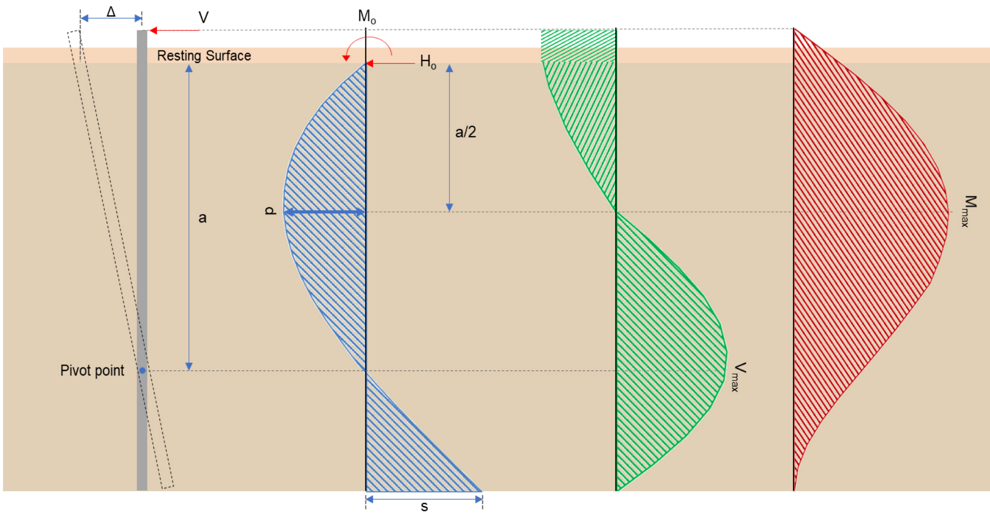
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.64009\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85345$$

Status: **PASS**
Ratio: **0.850**



Pile Rotation **Pressure Diagram** **Shear Diagram** **Moment Diagram**

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.842\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.13408\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.337\ \text{kipft}) + ((-0.842\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.92\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.92\ \text{kipft/ft})}{(-0.13408\ \text{kip/ft})}$$

$$E = 21.778\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.92\ \text{kipft/ft}) \times (5\ \text{ft})) + \left(3 \times (-0.13408\ \text{kip/ft}) \times (5\ \text{ft})^2\right)}{(6 \times (2.92\ \text{kipft/ft})) + (4 \times (-0.13408\ \text{kip/ft}) \times (5\ \text{ft}))}$$

$$a = 3.3886\ \text{ft}$$

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

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

$$V_{max} = ((-0.13408\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.778\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.3886\ \text{ft})}{(5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.778\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.3886\ \text{ft})}{(5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.4044\ \text{kip}$$

$$V_{max} = 4.4944 \text{ kip}$$

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

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

$$M_{max} = ((-0.13408 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(21.778 \text{ ft})}{(5 \text{ ft})} + \frac{(3.3886 \text{ ft})}{2 \times (5 \text{ ft})} \right) - \left[\left(\frac{4 \times (21.778 \text{ ft})}{(5 \text{ ft})} + 3 \right) \times \left(\frac{(3.3886 \text{ ft})}{2 \times (5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (21.778 \text{ ft})}{(5 \text{ ft})} + 2 \right) \times \left(\frac{(3.3886 \text{ ft})}{2 \times (5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 10.99 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(18.104 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -83.995 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\, [(-83.995 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.104\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0067674$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 18.104\ \text{kip} \rightarrow 18104\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18104 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.9 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.9 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.9 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.9 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.67 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.4944 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.4944 \text{ kip})}{(111.67 \text{ kip})}$$

$$Ratio = 0.040249$$

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

14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 10.99\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.99\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.044031$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

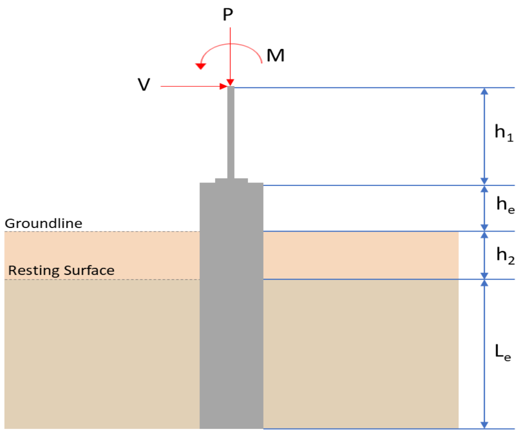
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \mathrm{in}$ - Pile width

$D = 48\ \mathrm{in}$ - Pile depth

$L = 5\ \mathrm{ft}$ - Total pile length

$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface

$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.396	17.194
V_x (kip)	-0.502	-0.840
V_z (kip)	-0.025	-0.042
M_x (kipft)	-0.129	-0.222
M_z (kipft)	9.668	18.469

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.502\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.079936\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.668\ \text{kipft}) + ((-0.502\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.5395\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.6545\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.025\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0039809\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.129\ \text{kipft}) + ((-0.025\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.020541\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.1127\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.6545\ \text{ft}), (1.1127\ \text{ft})]$$

$$L_{e,req} = 4.654\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.654\ \text{ft})}{(5\ \text{ft})}$$

$$Ratio = 0.9308$$

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

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

$$q = \frac{(10.396\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.64975\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.64975\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.32488$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.079936\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5395\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5395\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (1.5395\ \mathrm{kipft/ft})) + (4 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3948\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5395\ \mathrm{kipft/ft})) + (3 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^2}{(5\ \mathrm{ft})^2 \times [(3 \times (1.5395\ \mathrm{kipft/ft})) + (2 \times (-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.19317\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5395\ \mathrm{kipft/ft})) + ((-0.079936\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.64303\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.3948\ \mathrm{ft})}{2}$$

$$p_a = 0.25461\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.19317\ \mathrm{kip/ft^2}\right)}{\left(0.25461\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75868$$

Status: **PASS**
Ratio: **0.760**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.64303\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85738$$

Status: **PASS**
Ratio: **0.860**

Considering z-direction:

$H_o = -0.0039809\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.020541\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.020541\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.020541\ \mathrm{kipft/ft})) + (4 \times (-0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4969\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.020541\ \mathrm{kipft/ft})) + (3 \times (-0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^{2}}{(5\ \mathrm{ft})^2 \times [(3 \times (0.020541\ \mathrm{kipft/ft})) + (2 \times (-0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.00069323\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.020541\ \mathrm{kipft/ft})) + ((-0.0039809\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.0050828\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.4969\ \mathrm{ft})}{2}$$

$$p_a = 0.26226\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00069323\ \mathrm{kip/ft^2}\right)}{\left(0.26226\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0026433$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

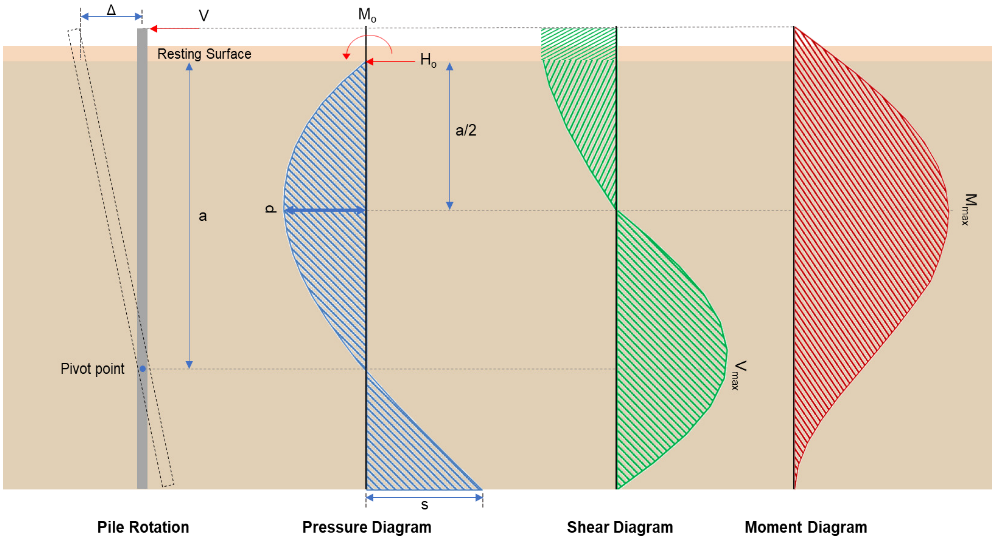
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0050828\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0067771$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.84\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.13376\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.469\ \mathrm{kipft}) + ((-0.84\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.9409\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.9409\ \mathrm{kipft/ft})}{(-0.13376\ \mathrm{kip/ft})}$$

$$E = 21.987\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.9409\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.13376\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (2.9409\ \mathrm{kipft/ft})) + (4 \times (-0.13376\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3882\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.13376\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.5235\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.13376\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5\ \mathrm{ft})) \times \left[\left(\frac{(21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + \frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.987\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3882\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 11.063\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.042\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0066879\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.222\ \mathrm{kipft}) + ((-0.042\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.03535\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.03535\ \mathrm{kipft/ft})}{(-0.0066879\ \mathrm{kip/ft})}$$

$$E = 5.2857\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.03535\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.0066879\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.03535\ \mathrm{kipft/ft})) + (4 \times (-0.0066879\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4945\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0066879 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.2857 \text{ ft})}{(5 \text{ ft})} + 3\right) \times \left(\frac{(3.4945 \text{ ft})}{(5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.2857 \text{ ft})}{(5 \text{ ft})} + 2\right) \times \left(\frac{(3.4945 \text{ ft})}{(5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.067704 \text{ kip}$$

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

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

$$M_{max} = ((-0.0066879 \text{ kip/ft}) \times (48 \text{ in}) \times (5 \text{ ft})) \times \left[\left(\frac{(5.2857 \text{ ft})}{(5 \text{ ft})} + \frac{(3.4945 \text{ ft})}{2 \times (5 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.2857 \text{ ft})}{(5 \text{ ft})} + 3\right) \times \left(\frac{(3.4945 \text{ ft})}{2 \times (5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.2857 \text{ ft})}{(5 \text{ ft})} + 2\right) \times \left(\frac{(3.4945 \text{ ft})}{2 \times (5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.1572 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(17.194 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.025 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.025 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

$$Ratio = \frac{(17.194\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0064272$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.194 \text{ kip} \rightarrow 17194 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17194 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.78 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.78 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.78 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.78 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.59 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.5235 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(4.5235\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.040538$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $V_{max} = 0.067704\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.067704\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.00060674$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 11.063\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(11.063\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.044324$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.1572\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.1572 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0006298$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

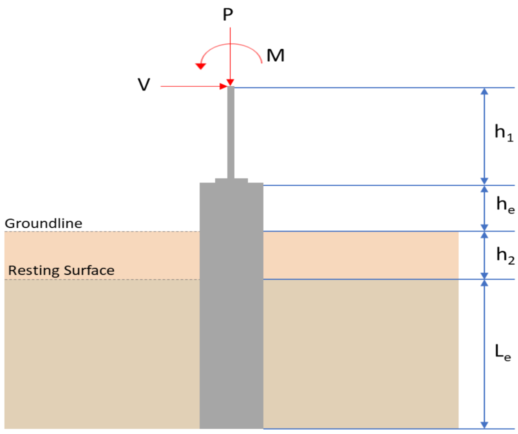
SkyCiv Foundation Design

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
$L = 5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.090	18.372
V_x (kip)	-0.510	-0.850
V_z (kip)	0.120	0.206
M_x (kipft)	0.629	1.092
M_z (kipft)	9.628	18.206

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.51 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.08121 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(9.628 \text{ kipft}) + ((-0.51 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.5331 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.6421 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.12 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.019108 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.629 \text{ kipft}) + ((0.12 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.10016 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.1915 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.6421 \text{ ft}), (2.1915 \text{ ft})]$$

$$L_{e,req} = 4.642 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.642 \text{ ft})}{(5 \text{ ft})}$$

$$Ratio = 0.9284$$

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

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

$$q = \frac{(11.09 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.69313 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.69313 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.34656$$

Status: **PASS**
Ratio: **0.350**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.08121 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 1.5331 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.5331 \text{ kipft/ft}) \times (5 \text{ ft})) + \left(3 \times (-0.08121 \text{ kip/ft}) \times (5 \text{ ft})^2\right)}{(6 \times (1.5331 \text{ kipft/ft})) + (4 \times (-0.08121 \text{ kip/ft}) \times (5 \text{ ft}))}$$

$$a = 3.3959 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.5331 \text{ kipft/ft})) + (3 \times (-0.08121 \text{ kip/ft}) \times (5 \text{ ft}))]^{\ 2}}{(5 \text{ ft})^2 \times [(3 \times (1.5331 \text{ kipft/ft})) + (2 \times (-0.08121 \text{ kip/ft}) \times (5 \text{ ft}))]}$$

$$p = 0.1913 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.5331 \text{ kipft/ft})) + ((-0.08121 \text{ kip/ft}) \times (5 \text{ ft}))]}{(5 \text{ ft})^2}$$

$$s = 0.63845 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.3959 \text{ ft})}{2}$$

$$p_a = 0.25469 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1913\ \mathrm{kip/ft^2}\right)}{\left(0.25469\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75113$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.63845\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85126$$

Status: **PASS**
Ratio: **0.850**

Considering z-direction:

$H_o = 0.019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10016\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10016\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.10016\ \mathrm{kipft/ft})) + (4 \times (0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4953\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.10016\ \mathrm{kipft/ft})) + (3 \times (0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]^{\ 2}}{(5\ \mathrm{ft})^2 \times [(3 \times (0.10016\ \mathrm{kipft/ft})) + (2 \times (0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}$$

$$p = 0.028826\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.10016\ \mathrm{kipft/ft})) + ((0.019108\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))]}{(5\ \mathrm{ft})^2}$$

$$s = 0.071006\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.4953\ \mathrm{ft})}{2}$$

$$p_a = 0.26215\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.028826\ \mathrm{kip/ft^2}\right)}{\left(0.26215\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.10996$$

Status: **PASS**
Ratio: **0.110**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5\ \mathrm{ft})$$

$$p_s = 0.75\ \mathrm{kip/ft^2}$$

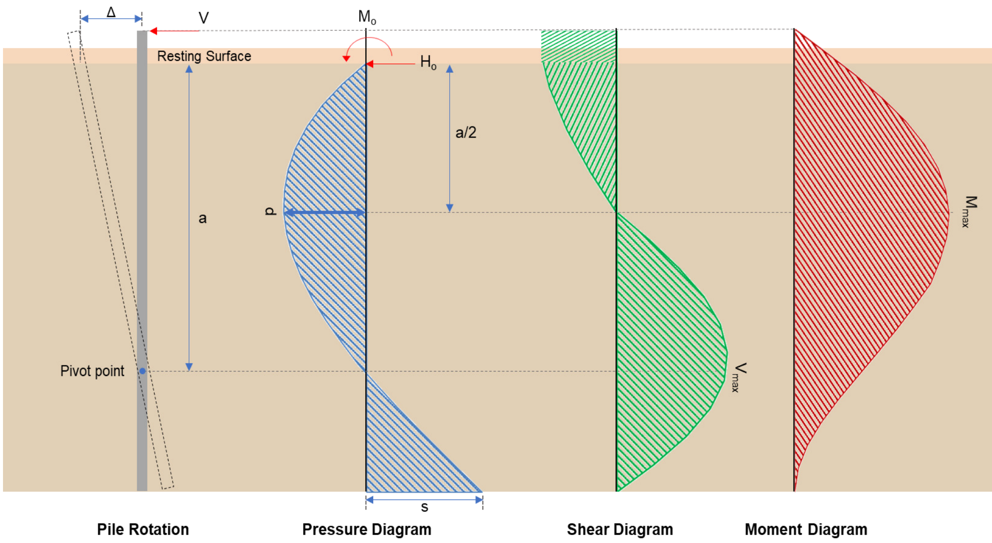
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.071006\ \mathrm{kip/ft^2}\right)}{\left(0.75\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.094675$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.85\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.13535\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.206\ \mathrm{kipft}) + ((-0.85\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 2.899\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.899\ \mathrm{kipft/ft})}{(-0.13535\ \mathrm{kip/ft})}$$

$$E = 21.419\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.899\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (-0.13535\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (2.899\ \mathrm{kipft/ft})) + (4 \times (-0.13535\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.3894\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.13535\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.419\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.419\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{(5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.468\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.13535\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5\ \mathrm{ft})) \times \left[\left(\frac{(21.419\ \mathrm{ft})}{(5\ \mathrm{ft})} + \frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.419\ \mathrm{ft})}{(5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.419\ \mathrm{ft})}{(5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.3894\ \mathrm{ft})}{2 \times (5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 10.922\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.206\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.032803\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.092\ \mathrm{kipft}) + ((0.206\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.17389\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17389\ \mathrm{kipft/ft})}{(0.032803\ \mathrm{kip/ft})}$$

$$E = 5.301\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17389\ \mathrm{kipft/ft}) \times (5\ \mathrm{ft})) + \left(3 \times (0.032803\ \mathrm{kip/ft}) \times (5\ \mathrm{ft})^2\right)}{(6 \times (0.17389\ \mathrm{kipft/ft})) + (4 \times (0.032803\ \mathrm{kip/ft}) \times (5\ \mathrm{ft}))}$$

$$a = 3.4942\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.032803\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.301\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.4942\ \text{ft})}{(5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.301\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.4942\ \text{ft})}{(5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33278\ \text{kip}$$

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

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

$$M_{max} = ((0.032803\ \text{kip/ft}) \times (48\ \text{in}) \times (5\ \text{ft})) \times \left[\left(\frac{(5.301\ \text{ft})}{(5\ \text{ft})} + \frac{(3.4942\ \text{ft})}{2 \times (5\ \text{ft})}\right) - \left[\left(\frac{4 \times (5.301\ \text{ft})}{(5\ \text{ft})} + 3\right) \times \left(\frac{(3.4942\ \text{ft})}{2 \times (5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.301\ \text{ft})}{(5\ \text{ft})} + 2\right) \times \left(\frac{(3.4942\ \text{ft})}{2 \times (5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.77279\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.372\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -83.986\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.986\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$Ratio = \frac{(18.372\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0068676$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.372 \text{ kip} \rightarrow 18372 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18372 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.93 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.93 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.93 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.69 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.468 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(4.468 \text{ kip})}{(111.69 \text{ kip})}$$ $$Ratio = 0.040004$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $V_{max} = 0.33278 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.33278 \text{ kip})}{(111.69 \text{ kip})}$$ $$Ratio = 0.0029795$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 10.922 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.922 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.043758$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $M_{max} = 0.77279 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.77279 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0030961$$	Status: **PASS** Ratio: **0.000**