Your Project Calculations

Project Name: Grover-GM-JB-Rev3

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Grover-GM-JB-Rev3&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/7_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=eCJfYzX542zx2n6mey2C3EgqhxxXoZ6AKLA6IZQjRnrCD3WAQ6MeyjG6EkAMkaGz

Array Specification

Product:	Beam
Unique ID:	4P-19.75-8TOP-SD-57-L-4Hx10W-195J
Duty Classification:	SD
Module Width:	40.00 in
Module Length:	91.10in
Number of Rows:	4
Number of Columns:	10
Total Number of Modules:	40
Desired Tilt Angle:	60
Front Edge Clearance:	6
Total Array Height at Tilt:	17.62 ft
Total Frame Length:	76.25 ft
Frame Weight:	3338 lbs
Array Dimensions N/S:	13.50 ft
Array Dimensions E/W:	76.75 ft
Rail Length:	162.00 in
Rail Spacing:	3.84 ft
Rail Check:	PASS (22% utilized)

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.85 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.50 ft Pile 2: 8.50 ft Pile 3: 8.50 ft Pile 4: 8.50 ft
Foundation Volume:	8.901 y^3
Foundation Result:	PASSED
Mount Twist:	0.073818 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	270 Avalanche Gulch Rd, Townsend, MT 59644, USA
Wind Speed:	100 mph
Snow Load:	35 psf
Design Uplift Pressure:	0.013582 ksf
Design Downforce Pressure:	-0.013582 ksf
Design Snow Pressure:	0.003849 ksf

Design Disclaimer

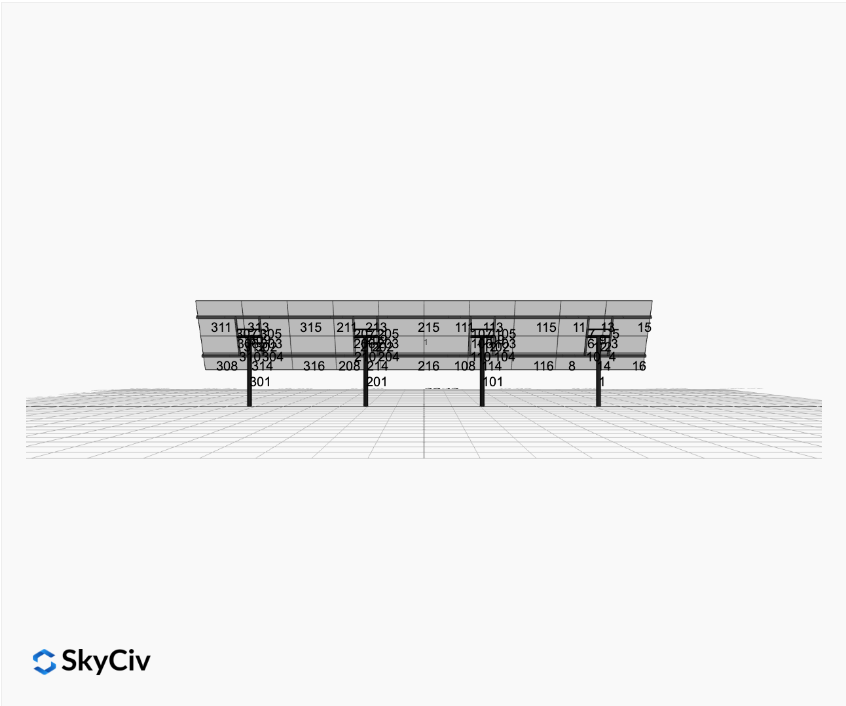
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

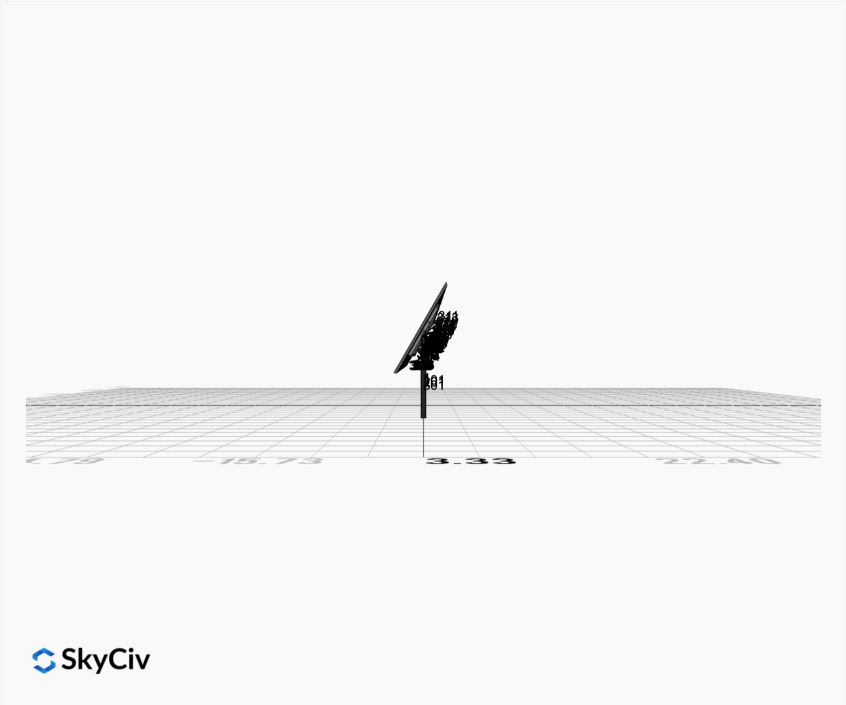
AutoDesigner Input

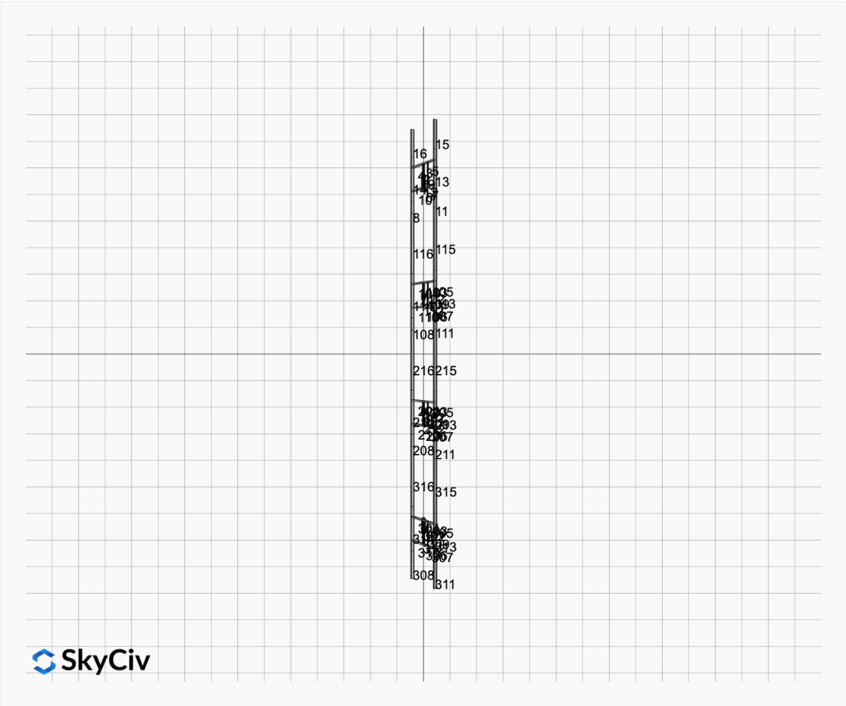
{"product_type":"Beam","project_id":"Grover-GM-JB-Rev3","site_address":"270 Avalanche Gulch Rd, Townsend, MT 59644, USA","module_width":40,"module_length":91.1,"number_rows":"4","number_columns":10,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":60,"ground_clearance":6,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"8_40","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":true,"wind_speed_override":100,"snow_load_override":35,"direct_snow_load":false}

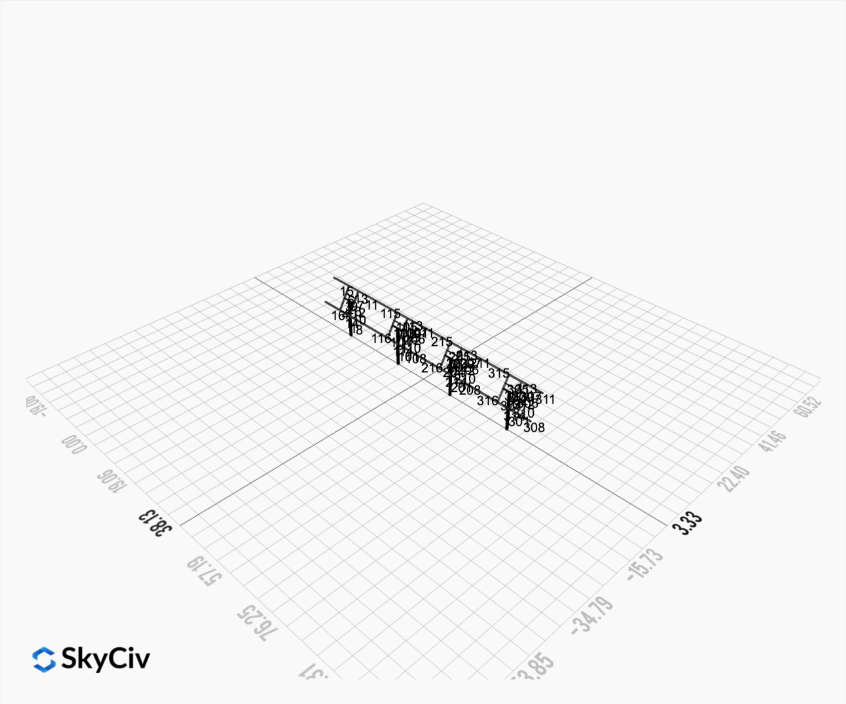
Design Notes:

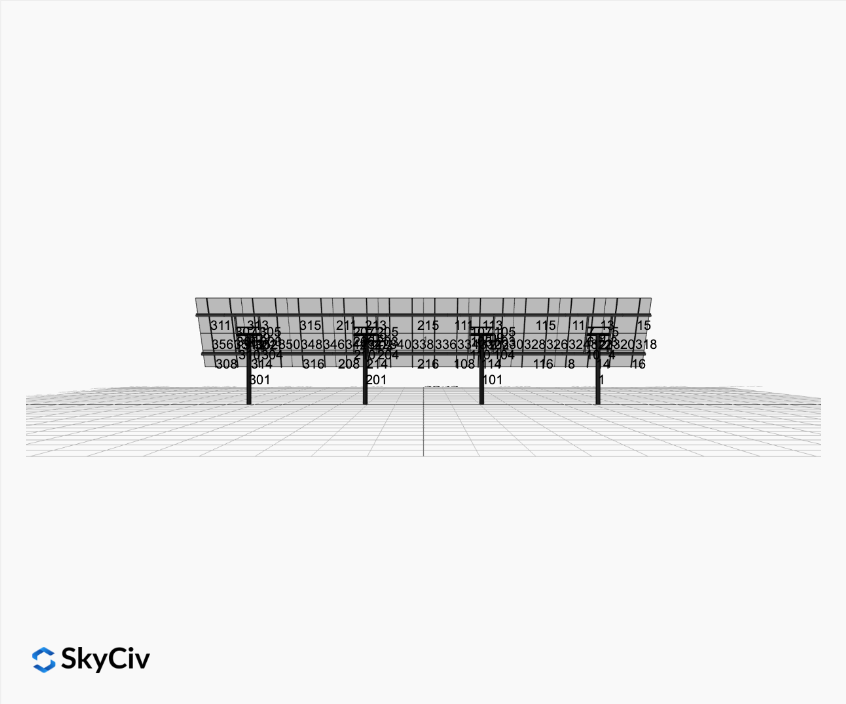
- AISC Deflection checks are set to L/1 due to structure design intent





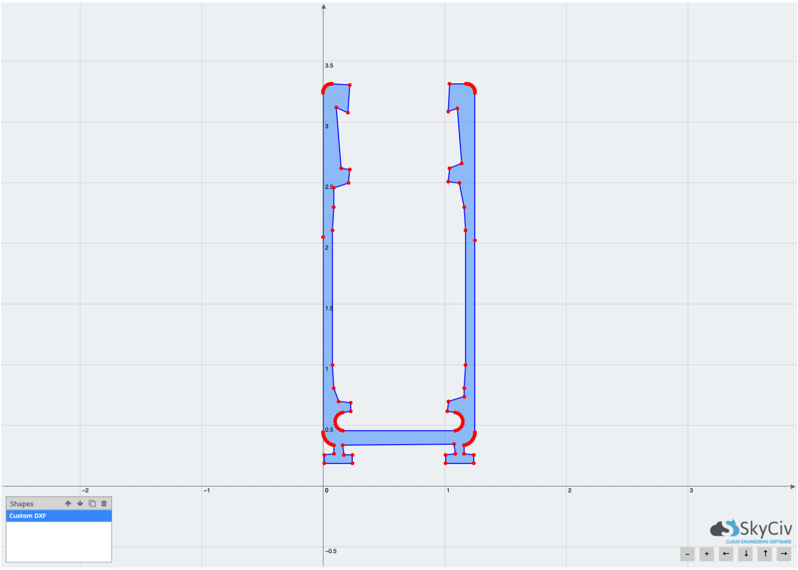




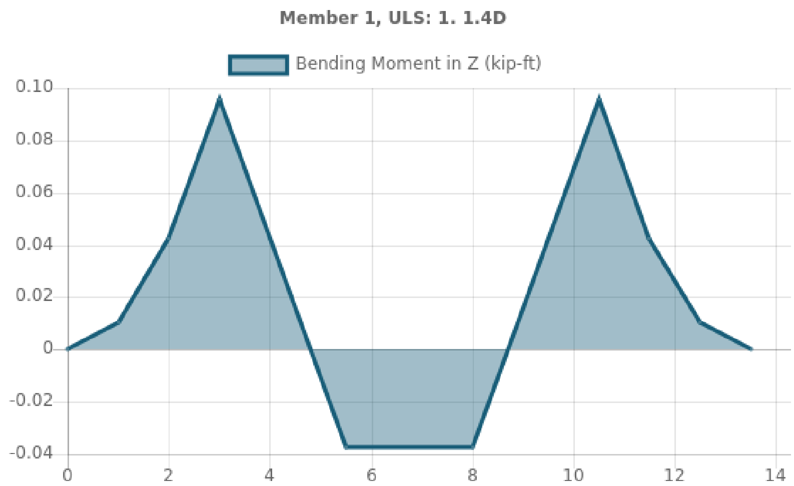


Rail Design Check

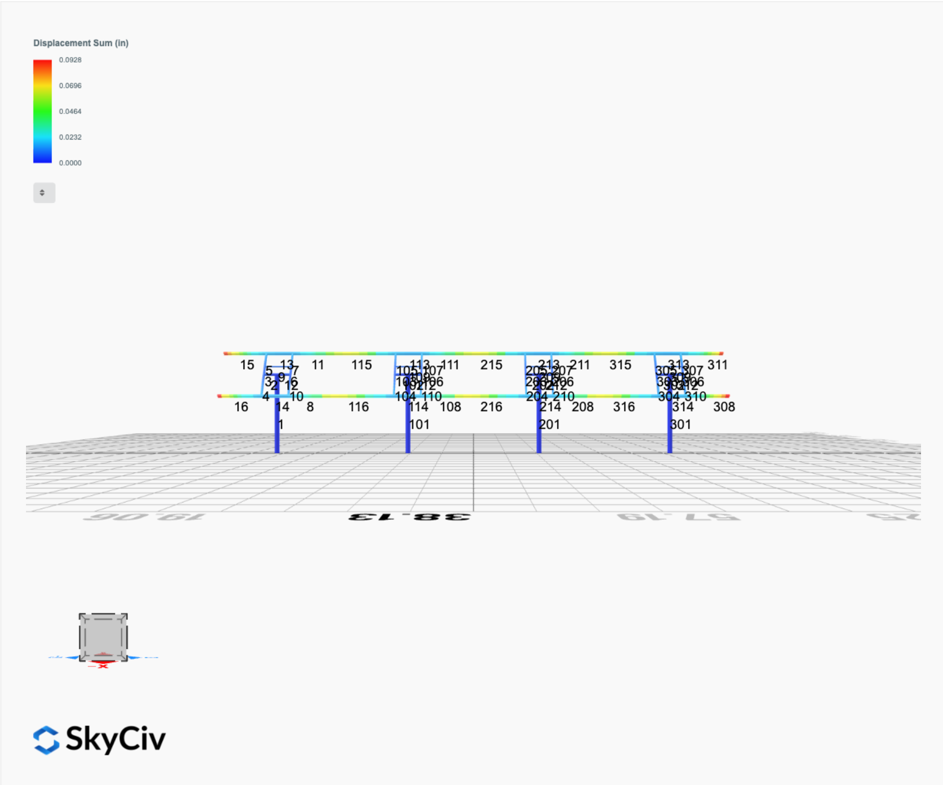
Rail Length: 13.5 ft
Additional Restraints Required: None
Tributary Width: 3.8375 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0074 kip/ft
Snow (Y): -0.0128 kip/ft
Wind uplift Case A: 0.0521 kip/ft
Wind downforce Case A: 0.0521 kip/ft
Dead (Panel load) (X): 0.0088 kip/ft
Dead (Panel load) (Y): -0.0152 kip/ft

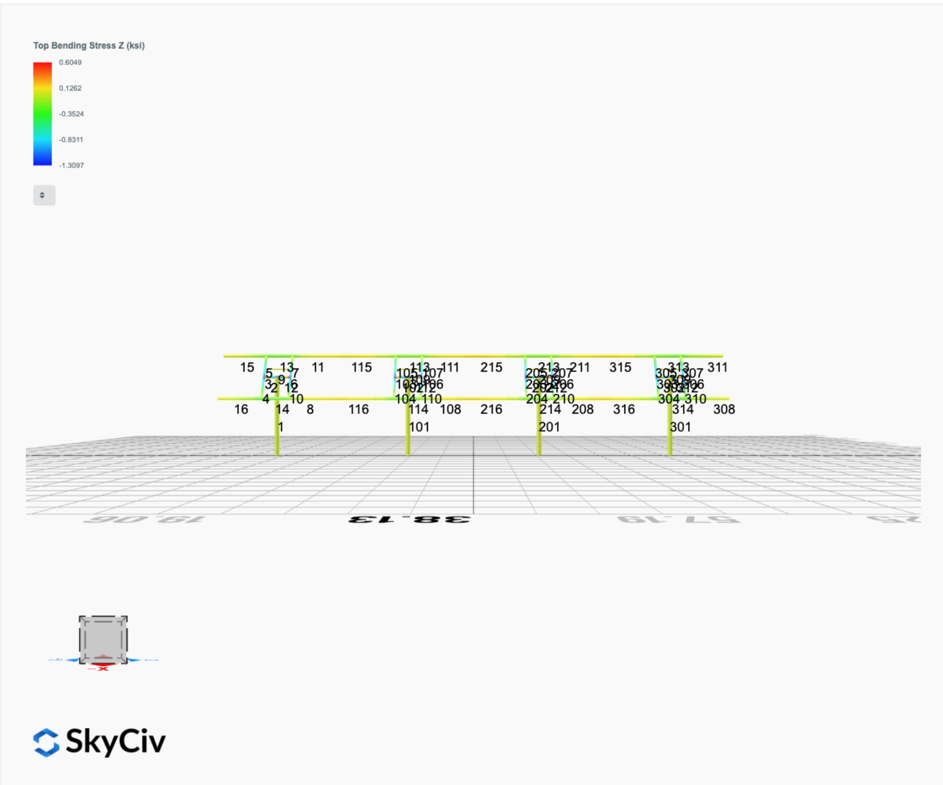


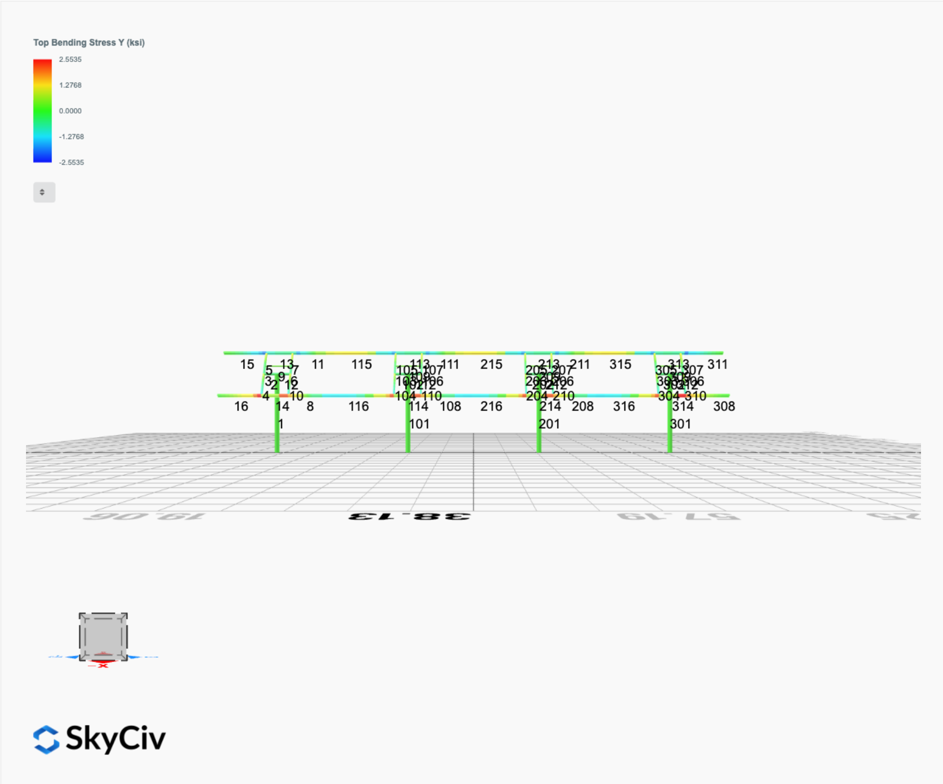
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	7.51329959	0.218	PASS
Material Yield	34.5	7.51329959	0.218	PASS
Material Strength	37	7.51329959	0.203	PASS

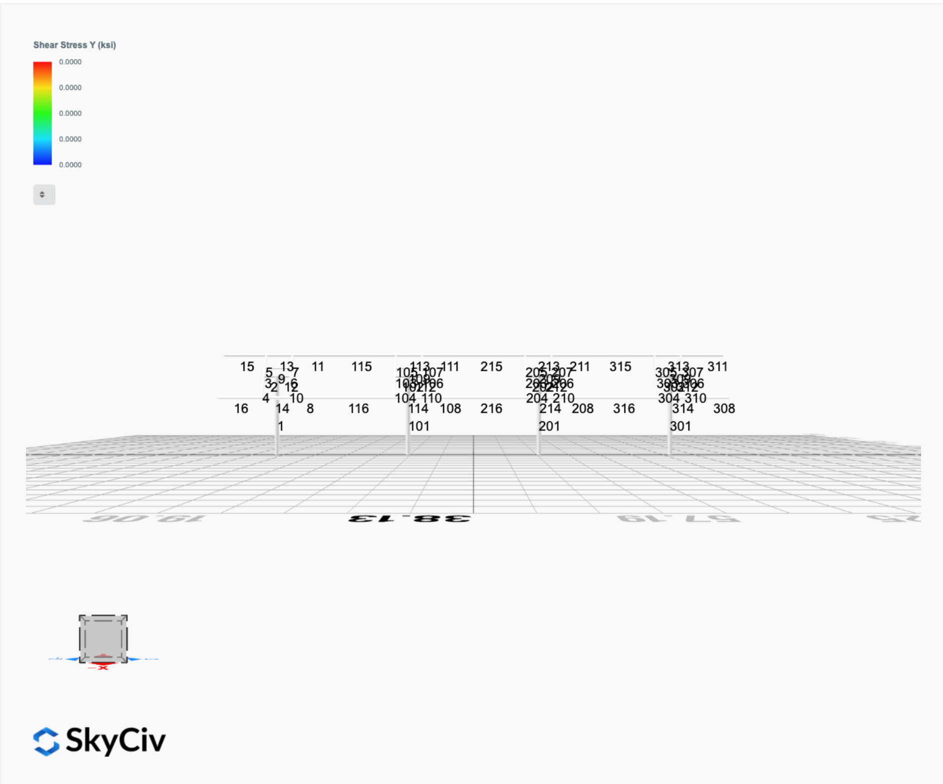


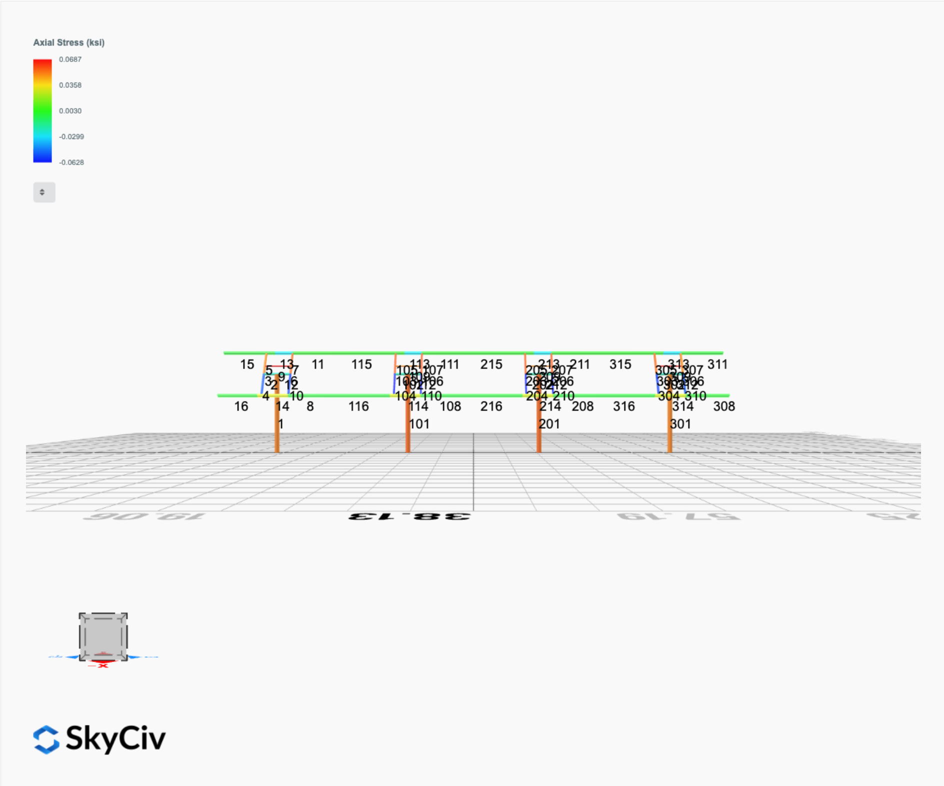
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
2.5535
1.2768
0.0000
-1.2768
-2.5535


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000


Axial Stress (ksi)
0.0687
0.0358
0.0030
-0.0299
-0.0628
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	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 2. D + L	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 3. D + (S or Lr or R)	-0.0041	2.4449	0.0030	0.0136	0.0491	0.0592
ULS: 3. D + (S or Lr or R)	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0038	2.3254	0.0028	0.0127	0.0461	0.0563
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 5b. D + 0.7E	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0038	2.3254	0.0028	0.0127	0.0461	0.0563
ULS: 8. 0.6D + 0.7E	-0.0018	1.1802	0.0013	0.0061	0.0223	0.0286
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7843	2.9910	0.0026	0.0109	0.0251	21.2837
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7779	0.9430	0.0021	0.0100	0.0478	-20.9539
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3397	3.0934	0.0031	0.0133	0.0371	15.9833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0038	2.3254	0.0028	0.0127	0.0461	0.0563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3319	1.5575	0.0027	0.0126	0.0541	-15.6948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0038	2.3254	0.0028	0.0127	0.0461	0.0563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3390	2.7350	0.0025	0.0107	0.0281	15.9747
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3326	1.1990	0.0021	0.0101	0.0452	-15.7035
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0031	1.9670	0.0022	0.0102	0.0372	0.0477
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7830	2.2042	0.0017	0.0068	0.0102	21.2646
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0018	1.1802	0.0013	0.0061	0.0223	0.0286
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7791	0.1562	0.0012	0.0060	0.0329	-20.9729
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0018	1.1802	0.0013	0.0061	0.0223	0.0286

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	4.3061
Shear X	-2.9732
Shear Z	0.0043
Moment X	0.0185
Moment Y (Twist)	0.0739
Moment Z	35.7889

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	3.0934
Shear X	-1.7843
Shear Z	0.0031
Moment X	0.0136
Moment Y (Twist)	0.0541
Moment Z	21.2837

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	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 2. D + L	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 3. D + (S or Lr or R)	0.0041	2.5866	0.0008	0.0030	-0.0082	-0.0327
ULS: 3. D + (S or Lr or R)	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0038	2.4585	0.0008	0.0029	-0.0077	-0.0301
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 5b. D + 0.7E	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0038	2.4585	0.0008	0.0029	-0.0077	-0.0301
ULS: 8. 0.6D + 0.7E	0.0018	1.2444	0.0004	0.0014	-0.0037	-0.0132
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8720	3.1610	0.0073	0.0239	-0.0672	22.2985
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8784	0.9871	-0.0059	-0.0189	0.0537	-22.0883
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4025	3.2737	0.0058	0.0191	-0.0535	16.7103
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0038	2.4585	0.0008	0.0029	-0.0077	-0.0301
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4103	1.6432	-0.0041	-0.0131	0.0372	-16.5798
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0038	2.4585	0.0008	0.0029	-0.0077	-0.0301
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4032	2.8893	0.0057	0.0185	-0.0520	16.7184
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4095	1.2589	-0.0043	-0.0136	0.0387	-16.5717
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0031	2.0741	0.0006	0.0023	-0.0062	-0.0220
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8732	2.3314	0.0071	0.0230	-0.0647	22.3073
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0018	1.2444	0.0004	0.0014	-0.0037	-0.0132
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8771	0.1575	-0.0062	-0.0198	0.0562	-22.0795
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0018	1.2444	0.0004	0.0014	-0.0037	-0.0132

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	4.5566
Shear X	-3.1294
Shear Z	0.0122
Moment X	0.0396
Moment Y (Twist)	0.1114
Moment Z	37.5278

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	3.2737
Shear X	-1.8784
Shear Z	0.0073
Moment X	0.0239
Moment Y (Twist)	0.0672
Moment Z	22.3073

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	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 2. D + L	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 3. D + (S or Lr or R)	0.0041	2.5866	-0.0008	-0.0030	0.0082	-0.0327
ULS: 3. D + (S or Lr or R)	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0038	2.4585	-0.0008	-0.0029	0.0077	-0.0301
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 5b. D + 0.7E	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0038	2.4585	-0.0008	-0.0029	0.0077	-0.0301
ULS: 8. 0.6D + 0.7E	0.0018	1.2444	-0.0004	-0.0014	0.0037	-0.0132
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8720	3.1610	-0.0073	-0.0239	0.0672	22.2985
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8784	0.9871	0.0059	0.0189	-0.0537	-22.0883
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4025	3.2737	-0.0058	-0.0190	0.0535	16.7103
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0038	2.4585	-0.0008	-0.0029	0.0077	-0.0301
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4103	1.6432	0.0041	0.0131	-0.0372	-16.5798
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0038	2.4585	-0.0008	-0.0029	0.0077	-0.0301

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4032	2.8893	-0.0057	-0.0185	0.0520	16.7184
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4095	1.2589	0.0043	0.0136	-0.0387	-16.5717
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0031	2.0741	-0.0006	-0.0023	0.0062	-0.0220
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8732	2.3314	-0.0071	-0.0230	0.0647	22.3073
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0018	1.2444	-0.0004	-0.0014	0.0037	-0.0132
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8771	0.1575	0.0062	0.0198	-0.0562	-22.0795
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0018	1.2444	-0.0004	-0.0014	0.0037	-0.0132

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	4.5566
Shear X	-3.1294
Shear Z	-0.0122
Moment X	-0.0396
Moment Y (Twist)	0.1114
Moment Z	37.5278

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	3.2737
Shear X	-1.8784
Shear Z	-0.0073
Moment X	-0.0239
Moment Y (Twist)	0.0672
Moment Z	22.3073

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	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 2. D + L	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 3. D + (S or Lr or R)	-0.0041	2.4449	-0.0030	-0.0136	-0.0491	0.0592
ULS: 3. D + (S or Lr or R)	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0038	2.3254	-0.0028	-0.0127	-0.0461	0.0563
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 5b. D + 0.7E	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0038	2.3254	-0.0028	-0.0127	-0.0461	0.0563
ULS: 8. 0.6D + 0.7E	-0.0018	1.1802	-0.0013	-0.0061	-0.0223	0.0286
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7843	2.9910	-0.0026	-0.0109	-0.0251	21.2837
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7779	0.9430	-0.0021	-0.0100	-0.0478	-20.9539
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3397	3.0934	-0.0031	-0.0133	-0.0370	15.9833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0038	2.3254	-0.0028	-0.0127	-0.0461	0.0563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3319	1.5575	-0.0027	-0.0126	-0.0541	-15.6948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0038	2.3254	-0.0028	-0.0127	-0.0461	0.0563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3390	2.7350	-0.0025	-0.0107	-0.0281	15.9747
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3326	1.1990	-0.0021	-0.0101	-0.0452	-15.7035
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0031	1.9670	-0.0022	-0.0102	-0.0372	0.0477
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7830	2.2042	-0.0017	-0.0068	-0.0102	21.2646
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0018	1.1802	-0.0013	-0.0061	-0.0223	0.0286
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7791	0.1562	-0.0012	-0.0060	-0.0329	-20.9729
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0018	1.1802	-0.0013	-0.0061	-0.0223	0.0286

Worst Case Reactions LRFD

Worst Case Reactions ASD

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	4.3061
Shear X	-2.9732
Shear Z	-0.0043
Moment X	-0.0185
Moment Y (Twist)	0.0738
Moment Z	35.7893

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	3.0934
Shear X	-1.7843
Shear Z	-0.0031
Moment X	-0.0136
Moment Y (Twist)	0.0541
Moment Z	21.2837

Project Details

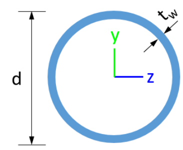
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

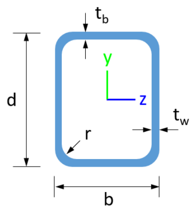
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

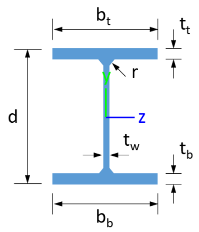
Section Dimensions



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



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	24.88	24.88	11.85	-	300	200	1
2	4	2.00	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
6	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
8	18	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.14,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
11	18	1.33	1.33	2.05	2.11,2.11,2.11,2.11,2.11,2.11,2.26,2.11,2.38,2.11,2.26,2.11,2.38,2.11,2.20,2.11,2.28,2.11,2.23,2.11,2.35,2.11,2.27,2.11,2.37,2.11	300	200	1
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.06,1.10,1.09,1.10,1.08,1.10,1.09,1.10,1.09,1.10	300	200	1
14	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.08,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10	300	200	1
15	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	24.88	24.88	11.85	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
104	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1

108	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.02,2.08,2.07,2.08,2.06,2.08,2.07,2.08,2.07,2.08	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
111	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.06,2.08,2.03,2.08,2.06,2.08,2.04,2.08,2.07,2.08,1.65,2.08,2.07,2.08,1.89,2.08,2.06,2.08,2.06,2.08	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.08,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.05,1.04	300	200	1
114	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.04,1.04	300	200	1
115	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.13,1.15,1.14,1.15,1.13,1.15,1.14,1.15,1.11,1.15,1.14,1.15,1.12,1.15,1.14,1.15,1.13,1.15	300	200	1
116	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.15,1.15	300	200	1
201	9	24.88	24.88	11.85	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
208	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.07,2.08,2.01,2.08,2.07,2.08,2.06,2.08,2.07,2.08,2.07,2.08	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
211	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.06,2.08,1.97,2.08,2.06,2.08,1.99,2.08,2.07,2.08,1.52,2.08,2.06,2.08,1.80,2.08,2.06,2.08,2.02,2.08	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.08,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.05,1.04	300	200	1
214	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.04,1.04	300	200	1
215	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.12,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.14,1.15	300	200	1
216	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15	300	200	1
301	9	24.88	24.88	11.85	-	300	200	1

302	4	1.30	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
305	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
306	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
307	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
308	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
311	18	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	4	2.00	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.06,1.10,1.09,1.10,1.08,1.10,1.09,1.10,1.09,1.10	300	200	1
314	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.08,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10	300	200	1
315	18	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.21,1.17,1.18,1.17,1.19,1.17,1.18,1.17,1.18,1.17	300	200	1
316	18	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	177.66	83.29	83.29	113.39	113.39
2	142.83	140.22	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	18.66	6.45	30.09	45.74
14	120.60	98.23	19.01	6.45	30.09	45.74
15	120.60	34.69	23.36	6.45	30.09	45.74
16	120.60	34.69	23.36	6.45	30.09	45.74
101	377.97	177.66	83.29	83.29	113.39	113.39
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61

103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	18.31	6.45	30.09	45.74
114	120.60	98.23	18.31	6.45	30.09	45.74
115	120.60	68.63	15.16	6.45	30.09	45.74
116	120.60	68.63	15.44	6.45	30.09	45.74
201	377.97	177.66	83.29	83.29	113.39	113.39
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61
208	120.60	117.88	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	117.88	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	18.31	6.45	30.09	45.74
214	120.60	98.23	18.31	6.45	30.09	45.74
215	120.60	68.63	15.30	6.45	30.09	45.74
216	120.60	68.63	15.57	6.45	30.09	45.74
301	377.97	177.66	83.29	83.29	113.39	113.39
302	142.83	141.72	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	4.60	29.14	16.61
304	79.65	72.01	10.99	4.60	29.14	16.61
305	79.65	73.44	10.99	4.60	29.14	16.61
306	79.65	74.02	10.99	4.60	29.14	16.61
307	79.65	73.44	10.99	4.60	29.14	16.61
308	120.60	34.69	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	4.60	29.14	16.61
311	120.60	34.69	23.36	6.45	30.09	45.74
312	142.83	140.22	16.17	16.17	42.85	42.85
313	120.60	98.23	18.66	6.45	30.09	45.74
314	120.60	98.23	19.01	6.45	30.09	45.74
315	120.60	68.63	15.98	6.45	30.09	45.74
316	120.60	68.63	15.98	6.45	30.09	45.74

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P, M_z, M_y)	Worst LC	KL/r	δ	Status
1	0.024	0.430	0.000	0.026	0.000	0.442	#13	0.508	Not Required	Pass
2	0.002	0.188	0.187	0.045	0.035	0.376	#13	0.053	Not Required	Pass
3	0.008	0.384	0.070	0.039	0.006	0.444	#13	0.044	Not Required	Pass
4	0.007	0.383	0.185	0.030	0.022	0.483	#13	0.078	Not Required	Pass

4	0.007	0.383	0.185	0.039	0.023	0.483	#13	0.078	Not Required	Pass
5	0.007	0.238	0.194	0.038	0.028	0.273	#13	0.073	Not Required	Pass
6	0.008	0.386	0.076	0.039	0.007	0.451	#13	0.044	Not Required	Pass
7	0.008	0.240	0.196	0.039	0.029	0.280	#13	0.073	Not Required	Pass
8	0.000	0.028	0.069	0.025	0.008	0.084	#21	0.088	Not Required	Pass
9	0.009	0.021	0.042	0.001	0.000	0.065	#13	0.198	Not Required	Pass
10	0.007	0.381	0.187	0.038	0.023	0.484	#13	0.078	Not Required	Pass
11	0.000	0.029	0.070	0.025	0.008	0.086	#21	0.088	Not Required	Pass
12	0.002	0.190	0.185	0.046	0.035	0.376	#13	0.034	Not Required	Pass
13	0.004	0.136	0.196	0.032	0.010	0.287	#13	0.265	Not Required	Pass
14	0.004	0.137	0.196	0.032	0.010	0.287	#13	0.177	Not Required	Pass
15	0.000	0.058	0.105	0.019	0.006	0.144	#21	Not Required	Not Required	Pass
16	0.000	0.058	0.105	0.019	0.006	0.144	#21	Not Required	Not Required	Pass
101	0.026	0.451	0.001	0.028	0.000	0.464	#13	0.508	Not Required	Pass
102	0.002	0.196	0.189	0.048	0.036	0.386	#13	0.034	Not Required	Pass
103	0.008	0.400	0.084	0.040	0.009	0.471	#13	0.044	Not Required	Pass
104	0.008	0.401	0.182	0.040	0.023	0.509	#13	0.078	Not Required	Pass
105	0.008	0.248	0.188	0.040	0.027	0.284	#13	0.073	Not Required	Pass
106	0.008	0.411	0.084	0.041	0.009	0.481	#13	0.044	Not Required	Pass
107	0.008	0.255	0.186	0.041	0.027	0.291	#13	0.073	Not Required	Pass
108	0.000	0.035	0.068	0.024	0.008	0.081	#21	0.088	Not Required	Pass
109	0.007	0.020	0.041	0.001	0.000	0.064	#13	0.198	Not Required	Pass
110	0.008	0.409	0.179	0.041	0.023	0.509	#13	0.078	Not Required	Pass
111	0.000	0.036	0.069	0.024	0.008	0.081	#21	0.088	Not Required	Pass
112	0.002	0.202	0.196	0.049	0.037	0.399	#13	0.034	Not Required	Pass
113	0.004	0.109	0.184	0.031	0.010	0.252	#21	0.265	Not Required	Pass
114	0.004	0.114	0.183	0.031	0.010	0.253	#21	0.265	Not Required	Pass
115	0.000	0.108	0.105	0.024	0.008	0.193	#13	0.439	Not Required	Pass
116	0.000	0.108	0.106	0.024	0.008	0.192	#13	0.439	Not Required	Pass
201	0.026	0.451	0.001	0.028	0.000	0.464	#13	0.508	Not Required	Pass
202	0.002	0.202	0.196	0.049	0.037	0.399	#13	0.034	Not Required	Pass
203	0.008	0.411	0.084	0.041	0.009	0.481	#13	0.044	Not Required	Pass
204	0.008	0.409	0.179	0.041	0.023	0.510	#13	0.078	Not Required	Pass
205	0.008	0.255	0.186	0.041	0.027	0.291	#13	0.073	Not Required	Pass
206	0.008	0.400	0.084	0.040	0.009	0.471	#13	0.044	Not Required	Pass
207	0.008	0.248	0.188	0.040	0.027	0.284	#13	0.073	Not Required	Pass
208	0.000	0.033	0.069	0.024	0.008	0.082	#21	0.088	Not Required	Pass
209	0.007	0.020	0.041	0.001	0.000	0.064	#13	0.198	Not Required	Pass
210	0.008	0.401	0.182	0.040	0.023	0.509	#13	0.078	Not Required	Pass
211	0.000	0.035	0.070	0.024	0.008	0.082	#21	0.088	Not Required	Pass
212	0.002	0.196	0.189	0.048	0.036	0.386	#13	0.034	Not Required	Pass
213	0.004	0.109	0.184	0.031	0.010	0.252	#21	0.265	Not Required	Pass
214	0.004	0.114	0.183	0.031	0.010	0.253	#21	0.265	Not Required	Pass
215	0.000	0.117	0.105	0.024	0.008	0.200	#13	0.439	Not Required	Pass
216	0.000	0.114	0.106	0.024	0.008	0.199	#13	0.439	Not Required	Pass
301	0.024	0.430	0.000	0.026	0.000	0.442	#13	0.508	Not Required	Pass
302	0.002	0.190	0.185	0.046	0.035	0.376	#13	0.034	Not Required	Pass
303	0.008	0.386	0.076	0.039	0.007	0.451	#13	0.044	Not Required	Pass
304	0.007	0.381	0.187	0.038	0.023	0.484	#13	0.078	Not Required	Pass
305	0.008	0.240	0.196	0.039	0.029	0.280	#13	0.073	Not Required	Pass
306	0.008	0.384	0.070	0.039	0.006	0.444	#13	0.044	Not Required	Pass
307	0.007	0.238	0.194	0.038	0.028	0.273	#13	0.073	Not Required	Pass
308	0.000	0.058	0.105	0.019	0.006	0.144	#21	Not Required	Not Required	Pass
309	0.009	0.021	0.042	0.001	0.000	0.065	#13	0.198	Not Required	Pass

310	0.007	0.383	0.185	0.039	0.023	0.483	#13	0.078	Not Required	Pass
311	0.000	0.058	0.105	0.019	0.006	0.144	#21	Not Required	Not Required	Pass
312	0.002	0.188	0.187	0.045	0.035	0.376	#13	0.053	Not Required	Pass
313	0.004	0.136	0.196	0.032	0.010	0.287	#13	0.177	Not Required	Pass
314	0.004	0.137	0.196	0.032	0.010	0.287	#13	0.265	Not Required	Pass
315	0.000	0.107	0.105	0.025	0.008	0.189	#13	0.439	Not Required	Pass
316	0.000	0.107	0.106	0.025	0.008	0.191	#13	0.439	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

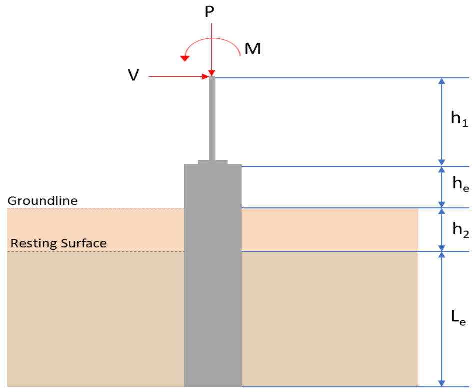
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - 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) $(\mathrm{psf/ft})$
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	3.093	4.306
V_x (kip)	-1.784	-2.973
V_z (kip)	0.003	0.004
M_x (kipft)	0.014	0.019
M_z (kipft)	21.284	35.789

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,

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

$$H_o = \frac{(-1.784\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.59467\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.284\ \text{kipft}) + ((-1.784\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.0947\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.7145\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.003\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.001\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.014\ \text{kipft}) + ((0.003\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.0046667\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.87474\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7145\ \text{ft}), (0.87474\ \text{ft})]$$

$$L_{e,req} = 7.714\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.714\ \text{ft})}{(8.5\ \text{ft})}$$

$$Ratio = 0.90753$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(3.093\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.43757\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.43757\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.21878$$

Status: **PASS**
Ratio: **0.220**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.59467\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.0947\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0947\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.59467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (7.0947\ \mathrm{kipft/ft})) + (4 \times (-0.59467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8948\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.0947\ \mathrm{kipft/ft})) + (3 \times (-0.59467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (7.0947\ \mathrm{kipft/ft})) + (2 \times (-0.59467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.25479\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.0947\ \mathrm{kipft/ft})) + ((-0.59467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.1916\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8948\ \mathrm{ft})}{2}$$

$$p_a = 0.44211\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.25479\ \mathrm{kip/ft^2})}{(0.44211\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.57631$$

Status: **PASS**
Ratio: **0.580**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1916\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9346$$

Status: PASS
Ratio: 0.930

Considering z-direction:

$H_o = 0.001\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0046667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0046667\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.0046667\ \mathrm{kipft/ft})) + (4 \times (0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.0551\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.0046667\ \mathrm{kipft/ft})) + (3 \times (0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.0046667\ \mathrm{kipft/ft})) + (2 \times (0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.001026\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.0046667\ \mathrm{kipft/ft})) + ((0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0023264\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0551\ \mathrm{ft})}{2}$$

$$p_a = 0.45413\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.001026\ \mathrm{kip/ft^2}\right)}{\left(0.45413\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0022592$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

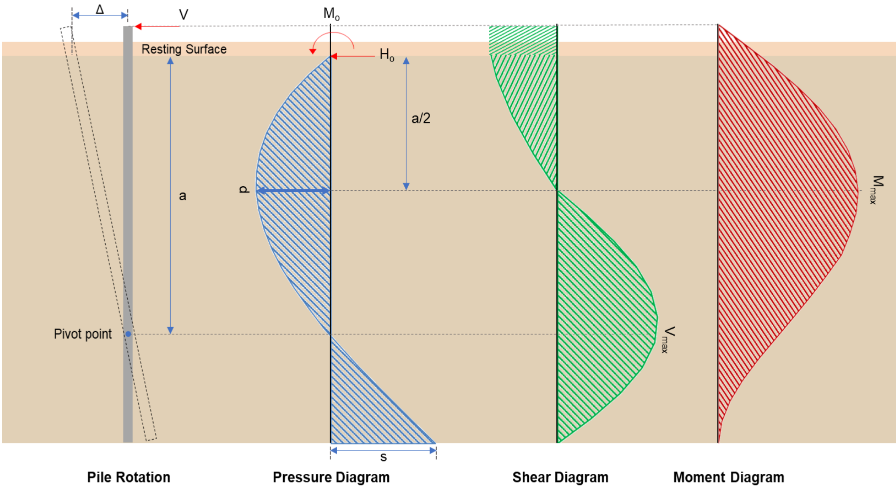
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0023264 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.0018246$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.973 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.991 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.789 \text{ kipft}) + ((-2.973 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 11.93 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.93 \text{ kipft/ft})}{(-0.991 \text{ kip/ft})}$$

$$E = 12.038 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.93 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.991 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (11.93 \text{ kipft/ft})) + (4 \times (-0.991 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8934 \text{ ft}$$

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

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

$$V_{max} = ((-0.991 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.038 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8934 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.038 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8934 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 9.4107\ \text{kip}$$

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

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

$$M_{max} = ((-0.991\ \text{kip/ft}) \times (36\ \text{in}) \times (8.5\ \text{ft})) \times \left[\left(\frac{(12.038\ \text{ft})}{(8.5\ \text{ft})} + \frac{(5.8934\ \text{ft})}{2 \times (8.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.038\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.8934\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.038\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.8934\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 37.707\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.004\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.0013333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.019\ \text{kipft}) + ((0.004\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.0063333\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0063333\ \text{kipft/ft})}{(0.0013333\ \text{kip/ft})}$$

$$E = 4.75\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0063333\ \text{kipft/ft}) \times (8.5\ \text{ft})) + \left(3 \times (0.0013333\ \text{kip/ft}) \times (8.5\ \text{ft})^2\right)}{(6 \times (0.0063333\ \text{kipft/ft})) + (4 \times (0.0013333\ \text{kip/ft}) \times (8.5\ \text{ft}))}$$

$$a = 6.052\ \text{ft}$$

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

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

$$V_{max} = ((0.0013333\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.75\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(6.052\ \text{ft})}{(8.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.75\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(6.052\ \text{ft})}{(8.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.006616\ \text{kip}$$

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

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

$$M_{max} = ((0.0013333\ \text{kip/ft}) \times (36\ \text{in}) \times (8.5\ \text{ft})) \times \left[\left(\frac{(4.75\ \text{ft})}{(8.5\ \text{ft})} + \frac{(6.052\ \text{ft})}{2 \times (8.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.75\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(6.052\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.75\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(6.052\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.025081 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.306 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.239 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.239 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.306\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.0034341$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\text{ in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\text{ in})$$

$$d = 28.8\text{ in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\text{ in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 186.09\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 4.306\text{ kip} \rightarrow 4306\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(4306\text{ lbf})}{6 \times \left(1017.9\text{ in}^2\right)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 75.169\text{ kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 204.04\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\text{ kip}), (75.169\text{ kip}), (204.04\text{ kip})\right]$$

$$V_c = 75.169 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.169 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 73.671 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.4107 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.4107 \text{ kip})}{(73.671 \text{ kip})}$$

$$Ratio = 0.12774$$

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

Considering z-direction:

$V_{max} = 0.006616 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.006616 \text{ kip})}{(73.671 \text{ kip})}$$

$$Ratio = 0.000089805$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

$$S_m = 4580.4\ \mathrm{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 62.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$

$$\phi M_n = 62.027\ \mathrm{kipft}$$

Considering x-direction:

$M_{max} = 37.707\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(37.707\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$

$$Ratio = 0.60792$$

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

Considering z-direction:

$M_{max} = 0.025081\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.025081\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$

$$Ratio = 0.00040435$$

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

REFERENCES	CALCULATIONS	RESULTS

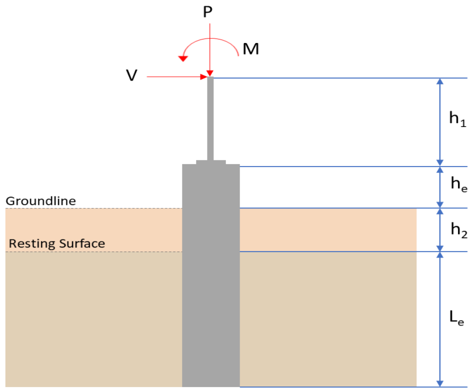
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - 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)	3.274	4.557
V_x (kip)	-1.878	-3.129
V_z (kip)	0.007	0.012
M_x (kipft)	0.024	0.040
M_z (kipft)	22.307	37.528

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,

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

$$H_o = \frac{(-1.878\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.626\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.307\ \text{kipft}) + ((-1.878\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.4357\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.7983\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.007\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.0023333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.024\ \text{kipft}) + ((0.007\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.008\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.0747\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7983\ \text{ft}), (1.0747\ \text{ft})]$$

$$L_{e,req} = 7.798\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.798\ \text{ft})}{(8.5\ \text{ft})}$$

$$Ratio = 0.91741$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(3.274\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.46318\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46318\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23159$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.626\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.4357\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.4357\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (7.4357\ \mathrm{kipft/ft})) + (4 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8954\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.4357\ \mathrm{kipft/ft})) + (3 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (7.4357\ \mathrm{kipft/ft})) + (2 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.2654\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.4357\ \mathrm{kipft/ft})) + ((-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.2458\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8954\ \mathrm{ft})}{2}$$

$$p_a = 0.44216\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2654\ \mathrm{kip/ft^2}\right)}{\left(0.44216\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.60024$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2458\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97713$$

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

Considering z-direction:

$H_o = 0.0023333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.008\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.008\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.008\ \mathrm{kipft/ft})) + (4 \times (0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.108\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.008\ \mathrm{kipft/ft})) + (3 \times (0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.008\ \mathrm{kipft/ft})) + (2 \times (0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.0021441\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.008\ \mathrm{kipft/ft})) + ((0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0046745\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.108\ \mathrm{ft})}{2}$$

$$p_a = 0.4581\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0021441\ \mathrm{kip/ft^2}\right)}{\left(0.4581\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0046803$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

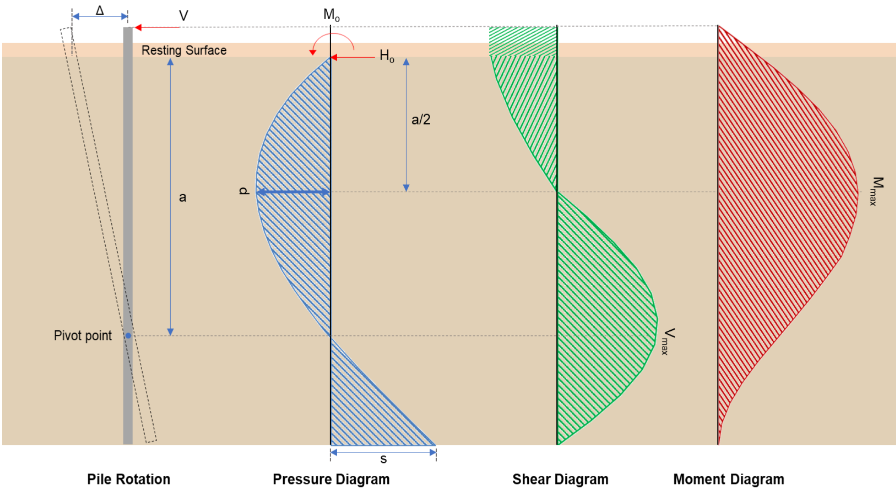
$$Ratio = \frac{s}{}$$

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

$$Ratio = \frac{(0.0046745\ \mathrm{kip/ft^2})}{(1.275\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0036662$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.129\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.043\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.528\ \mathrm{kipft}) + ((-3.129\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 12.509\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.509\ \mathrm{kipft/ft})}{(-1.043\ \mathrm{kip/ft})}$$

$$E = 11.994\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.509\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-1.043\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (12.509\ \mathrm{kipft/ft})) + (4 \times (-1.043\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.894\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.043\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.994\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.894\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.994\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.894\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8756 \text{ kip}$$

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

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

$$M_{max} = ((-1.043 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(11.994 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.994 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.994 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 39.563 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.012 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.004 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.04 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.013333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.013333 \text{ kipft/ft})}{(0.004 \text{ kip/ft})}$$

$$E = 3.3333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.013333 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (0.004 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.013333 \text{ kipft/ft})) + (4 \times (0.004 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1127 \text{ ft}$$

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

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

$$V_{max} = ((0.004 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1127 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1127 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.016352 \text{ kip}$$

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

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

$$M_{max} = ((0.004 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.3333 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.060428 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.557 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.231 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.231 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.557\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0036342$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 4.557\ \text{kip} \rightarrow 4557\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(4557\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.212\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.212\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.212\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.212\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.698\ \text{kip}$$

Considering x-direction:

$V_{max} = 9.8756\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.8756\ \text{kip})}{(73.698\ \text{kip})}$$

$$Ratio = 0.134$$

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

Considering z-direction:

$V_{max} = 0.016352\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.016352\ \text{kip})}{(73.698\ \text{kip})}$$

$$Ratio = 0.00022188$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$S_m = 4580.4\ \mathrm{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 39.563\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(39.563\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.63784$$	Status: **PASS** Ratio: **0.640**
	Considering z-direction: $M_{max} = 0.060428\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.060428\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.00097423$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

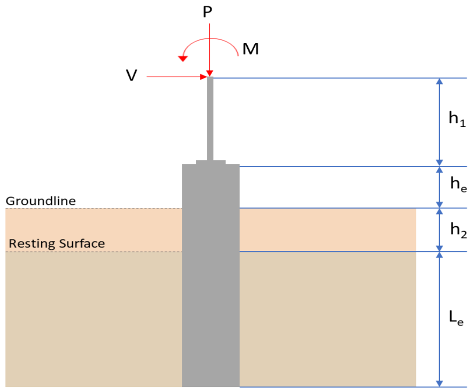
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - 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) $(\mathrm{psf/ft})$
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	3.274	4.557
V_x (kip)	-1.878	-3.129
V_z (kip)	-0.007	-0.012
M_x (kipft)	-0.024	-0.040
M_z (kipft)	22.307	37.528

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,

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

$$H_o = \frac{(-1.878\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.626\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.307\ \text{kipft}) + ((-1.878\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.4357\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.7983\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.007\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.0023333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.024\ \text{kipft}) + ((-0.007\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.008\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.92883\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7983\ \text{ft}), (0.92883\ \text{ft})]$$

$$L_{e,req} = 7.798\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.798\ \text{ft})}{(8.5\ \text{ft})}$$

$$Ratio = 0.91741$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(3.274\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.46318\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46318\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23159$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.626\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.4357\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.4357\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (7.4357\ \mathrm{kipft/ft})) + (4 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8954\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\ M_o) + (3\ H_o\ L_e)]^2}{L_e^2\ [(3\ M_o) + (2\ H_o\ L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.4357\ \mathrm{kipft/ft})) + (3 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (7.4357\ \mathrm{kipft/ft})) + (2 \times (-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.2654\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\ M_o) + (H_o\ L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.4357\ \mathrm{kipft/ft})) + ((-0.626\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.2458\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8954\ \mathrm{ft})}{2}$$

$$p_a = 0.44216\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2654\ \mathrm{kip/ft^2}\right)}{\left(0.44216\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.60024$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2458\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97713$$

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

Considering z-direction:

$H_o = -0.0023333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.008\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.008\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.008\ \mathrm{kipft/ft})) + (4 \times (-0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.108\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.008\ \mathrm{kipft/ft})) + (3 \times (-0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\,2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.008\ \mathrm{kipft/ft})) + (2 \times (-0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.00078704\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.008\ \mathrm{kipft/ft})) + ((-0.0023333\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})]}{(8.5\ \mathrm{ft})^2}$$

$$s = -0.00050006\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.108\ \mathrm{ft})}{2}$$

$$p_a = 0.4581\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00078704\ \mathrm{kip/ft^2}\right)}{\left(0.4581\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0017181$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

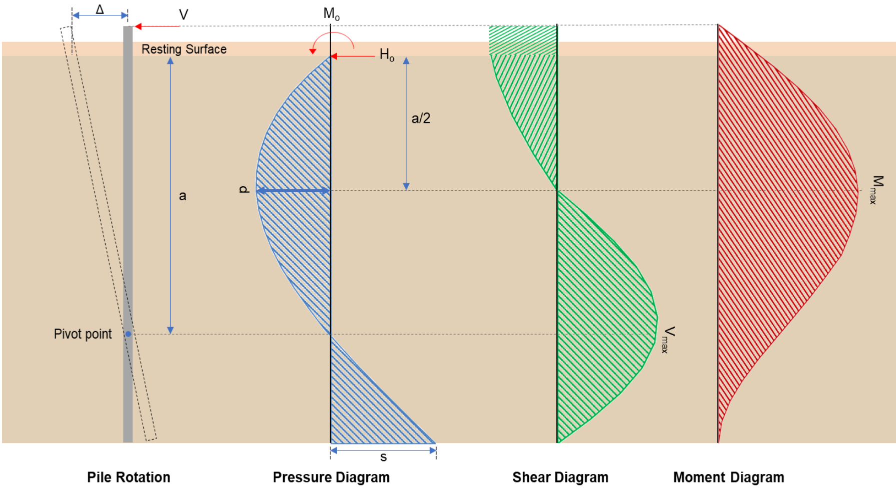
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(-0.00050006\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0003922$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.129\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.043\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.528\ \mathrm{kipft}) + ((-3.129\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 12.509\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.509\ \mathrm{kipft/ft})}{(-1.043\ \mathrm{kip/ft})}$$

$$E = 11.994\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.509\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-1.043\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (12.509\ \mathrm{kipft/ft})) + (4 \times (-1.043\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.894\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.043\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.994\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.894\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.994\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.894\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8756 \text{ kip}$$

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

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

$$M_{max} = ((-1.043 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(11.994 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.994 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.994 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.894 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 39.563 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.012 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.004 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.04 \text{ kipft}) + ((-0.012 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.013333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.013333 \text{ kipft/ft})}{(-0.004 \text{ kip/ft})}$$

$$E = 3.3333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.013333 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.004 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.013333 \text{ kipft/ft})) + (4 \times (-0.004 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1127 \text{ ft}$$

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

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

$$V_{max} = ((-0.004 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1127 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1127 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.016352 \text{ kip}$$

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

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

$$M_{max} = ((-0.004 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.3333 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3333 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1127 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.060428 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.557 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.231 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.231 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.557\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0036342$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 4.557\ \text{kip} \rightarrow 4557\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(4557\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.212\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.212\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.212\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.212\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.698\ \text{kip}$$

Considering x-direction:

$V_{max} = 9.8756\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.8756\ \text{kip})}{(73.698\ \text{kip})}$$

$$Ratio = 0.134$$

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

Considering z-direction:

$V_{max} = 0.016352\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.016352\ \text{kip})}{(73.698\ \text{kip})}$$

$$Ratio = 0.00022188$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$S_m = 4580.4 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 39.563 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(39.563 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.63784$$	Status: **PASS** Ratio: **0.640**
	Considering z-direction: $M_{max} = 0.060428 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.060428 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.00097423$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

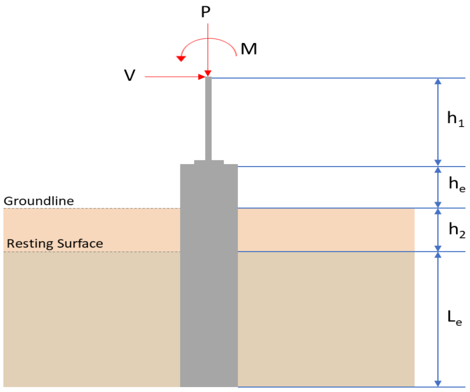
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - 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) $(\mathrm{psf/ft})$
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
$P\ (\mathrm{kip})$	3.093	4.306
$V_x\ (\mathrm{kip})$	-1.784	-2.973
$V_z\ (\mathrm{kip})$	-0.003	-0.004
$M_x\ (\mathrm{kipft})$	-0.014	-0.018
$M_z\ (\mathrm{kipft})$	21.284	35.789

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,

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

$$H_o = \frac{(-1.784\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.59467\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.284 \text{ kipft}) + ((-1.784 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.0947 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.7145 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.003 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.001 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.014 \text{ kipft}) + ((-0.003 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.0046667 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.79973 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7145 \text{ ft}), (0.79973 \text{ ft})]$$

$$L_{e,req} = 7.714 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.714 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.90753$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(3.093 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.43757 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.43757 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.21878$$

Status: **PASS**
Ratio: **0.220**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.59467 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.0947 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0947 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.59467 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (7.0947 \text{ kipft/ft})) + (4 \times (-0.59467 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8948 \text{ ft}$$

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

$$p = \frac{1.178\, \left[(4\, M_o) + (3\, H_o\, L_e)\right]^2}{L_e^2\, \left[(3\, M_o) + (2\, H_o\, L_e)\right]}$$

$$p = \frac{1.178 \times \left[(4 \times (7.0947 \text{ kipft/ft})) + (3 \times (-0.59467 \text{ kip/ft}) \times (8.5 \text{ ft}))\right]^2}{(8.5 \text{ ft})^2 \times \left[(3 \times (7.0947 \text{ kipft/ft})) + (2 \times (-0.59467 \text{ kip/ft}) \times (8.5 \text{ ft}))\right]}$$

$$p = 0.25479 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, \left[(2\, M_o) + (H_o\, L_e)\right]}{L_e^2}$$

$$s = \frac{9.425 \times \left[(2 \times (7.0947 \text{ kipft/ft})) + ((-0.59467 \text{ kip/ft}) \times (8.5 \text{ ft}))\right]}{(8.5 \text{ ft})^2}$$

$$s = 1.1916 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8948 \text{ ft})}{2}$$

$$p_a = 0.44211 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25479 \text{ kip/ft}^2\right)}{\left(0.44211 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.57631$$

Status: **PASS**
Ratio: **0.580**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1916\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9346$$

Status: PASS
Ratio: 0.930

Considering z-direction:

$H_o = -0.001\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0046667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0046667\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.0046667\ \mathrm{kipft/ft})) + (4 \times (-0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.0551\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.0046667\ \mathrm{kipft/ft})) + (3 \times (-0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.0046667\ \mathrm{kipft/ft})) + (2 \times (-0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.00025378\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.0046667\ \mathrm{kipft/ft})) + ((-0.001\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.00010871\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0551\ \mathrm{ft})}{2}$$

$$p_a = 0.45413\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00025378\ \mathrm{kip/ft^2}\right)}{\left(0.45413\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00055882$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

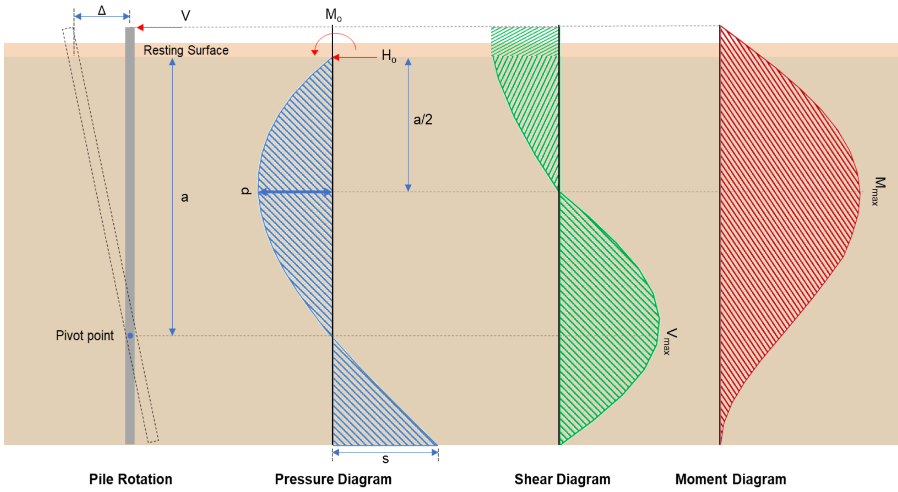
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00010871\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000085261$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.973\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.991\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.789\ \mathrm{kipft}) + ((-2.973\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 11.93\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.93\ \mathrm{kipft/ft})}{(-0.991\ \mathrm{kip/ft})}$$

$$E = 12.038\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.93\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.991\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (11.93\ \mathrm{kipft/ft})) + (4 \times (-0.991\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8934\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.991\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.038\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8934\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.038\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8934\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.4107 \text{ kip}$$

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

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

$$M_{max} = ((-0.991 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(12.038 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8934 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.038 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8934 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.038 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8934 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 37.707 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.004 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0013333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.018 \text{ kipft}) + ((-0.004 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.006 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.006 \text{ kipft/ft})}{(-0.0013333 \text{ kip/ft})}$$

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.006 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.0013333 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.006 \text{ kipft/ft})) + (4 \times (-0.0013333 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0615 \text{ ft}$$

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

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

$$V_{max} = ((-0.0013333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.0615 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.0615 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.00641 \text{ kip}$$

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

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

$$M_{max} = ((-0.0013333 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(4.5 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.0615 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (4.5 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.0615 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.0615 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.024207 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.306 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.239 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.239 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.306\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.0034341$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\text{ in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\text{ in})$$

$$d = 28.8\text{ in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\text{ in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 186.09\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 4.306\text{ kip} \rightarrow 4306\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(4306\text{ lbf})}{6 \times \left(1017.9\text{ in}^2\right)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 75.169\text{ kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 204.04\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\text{ kip}), (75.169\text{ kip}), (204.04\text{ kip})\right]$$

$$V_c = 75.169\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.169\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.671\ \text{kip}$$

Considering x-direction:

$V_{max} = 9.4107\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.4107\ \text{kip})}{(73.671\ \text{kip})}$$

$$Ratio = 0.12774$$

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

Considering z-direction:

$V_{max} = 0.00641\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.00641\ \text{kip})}{(73.671\ \text{kip})}$$

$$Ratio = 0.000087009$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 37.707\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(37.707\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.60792$$	Status: **PASS** Ratio: **0.610**
	Considering z-direction: $M_{max} = 0.024207\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.024207\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.00039027$$	Status: **PASS** Ratio: **0.000**