Your Project Calculations

Project Name: Marion Severson

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Marion%20Severson&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/2_2024

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=Z03URnIdUMzLj77Q1HSgj6aTXQDFZOVvkZlvHUDTuxHloz7TjPGfATHf6NDGXLMC

Array Specification

Product:	Beam
Unique ID:	4P-19.75-6TOP-XD-12-L-4Hx12W-F2F5
Duty Classification:	XD
Module Width:	44.60 in
Module Length:	67.80in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Desired Tilt Angle:	30
Front Edge Clearance:	3
Total Array Height at Tilt:	10.47 ft
Total Frame Length:	68.75 ft
Frame Weight:	3252 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	68.80 ft
Rail Length:	180.40 in
Rail Spacing:	2.82 ft
Rail Check:	Not Checked

Support Specifications

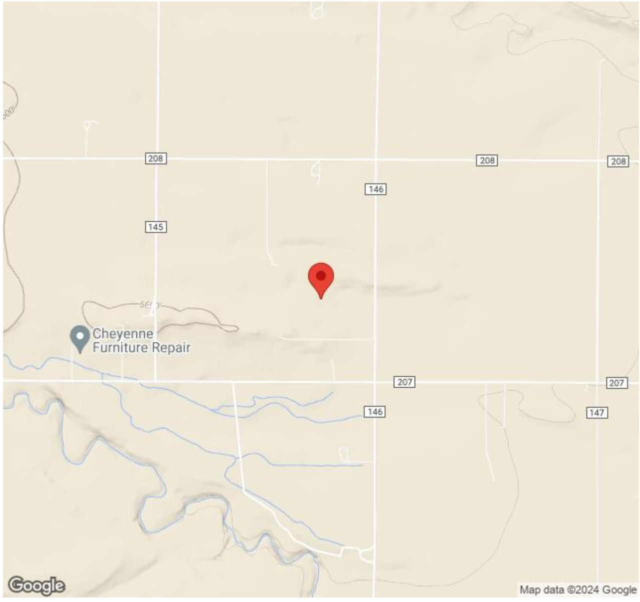
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	6.76 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 7.75 ft Pile 3: 7.75 ft Pile 4: 7.50 ft
Foundation Volume:	7.985 y^3
Foundation Result:	PASSED
Mount Twist:	1.077423 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	740 Co Rd 146, Carpenter, WY 82054, USA
Wind Speed:	103 mph
Snow Load:	20 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.008797 ksf



Design Disclaimer

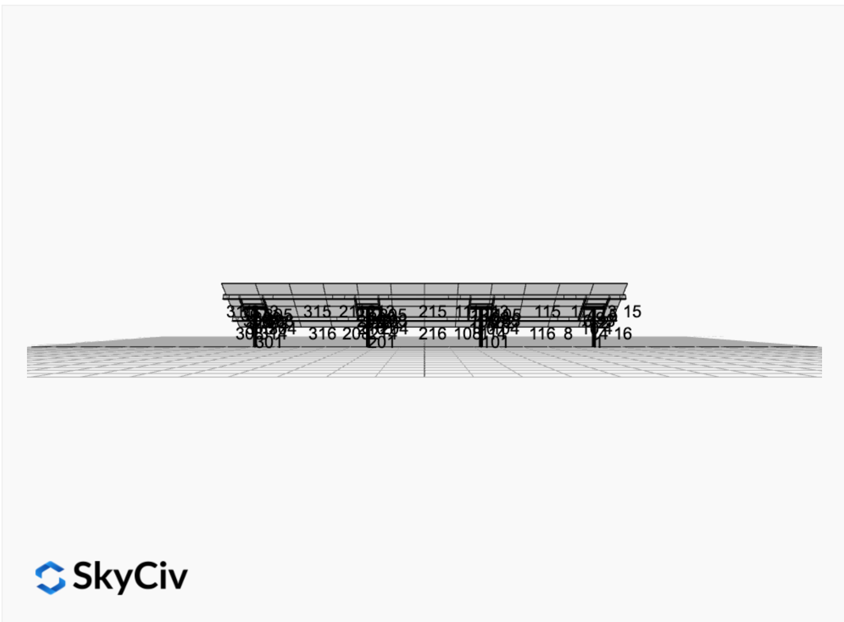
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

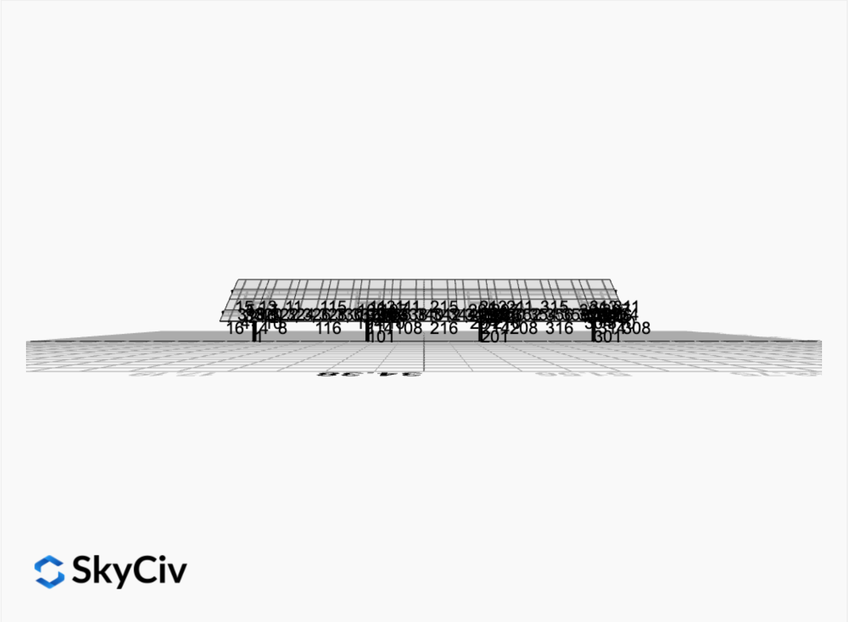
AutoDesigner Input

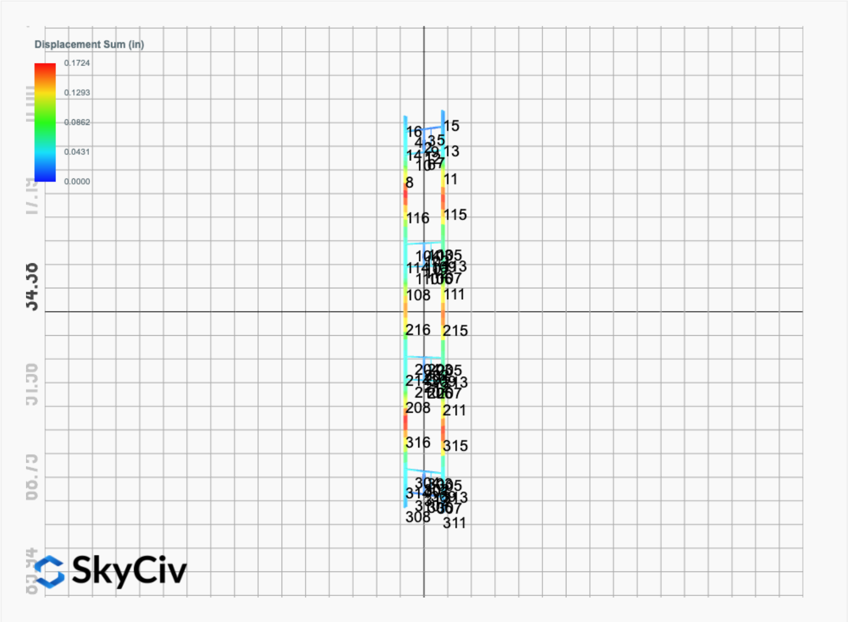

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","project_id":"Marion Severson","site_address":"740 Co Rd 146, Carpenter, WY 82054, USA","module_width":44.6,"module_length":67.8,"number_rows":"4","number_columns":12,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":30,"ground_clearance":3,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false}
```

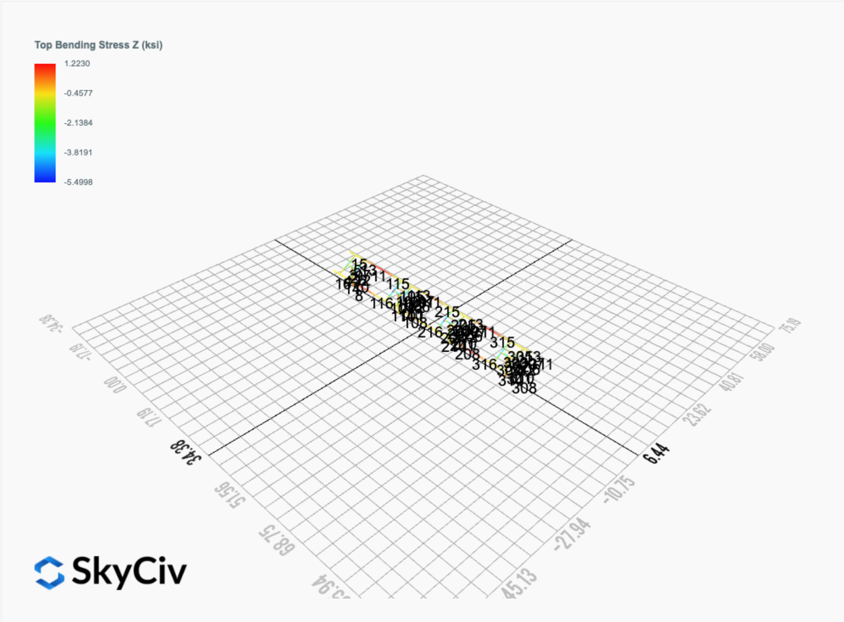

Design Notes:

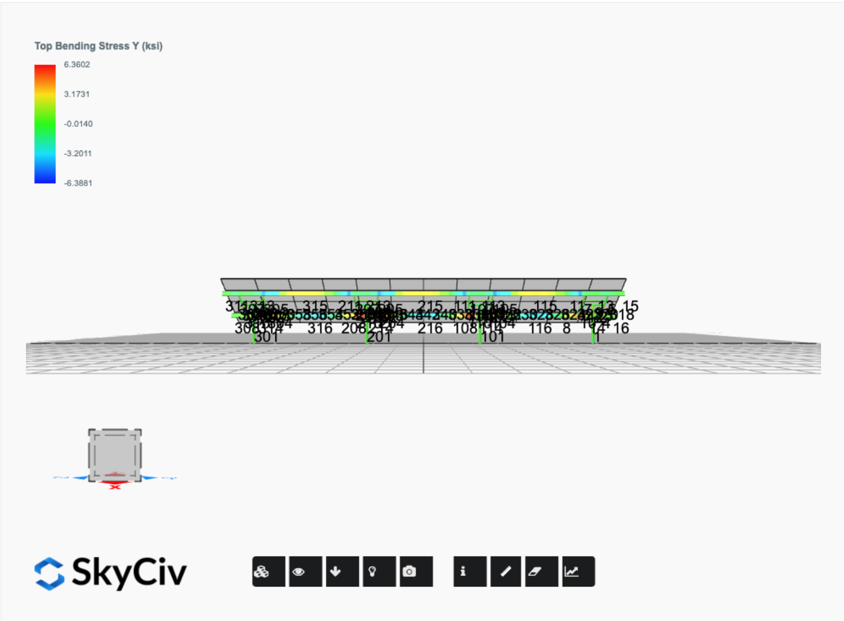
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



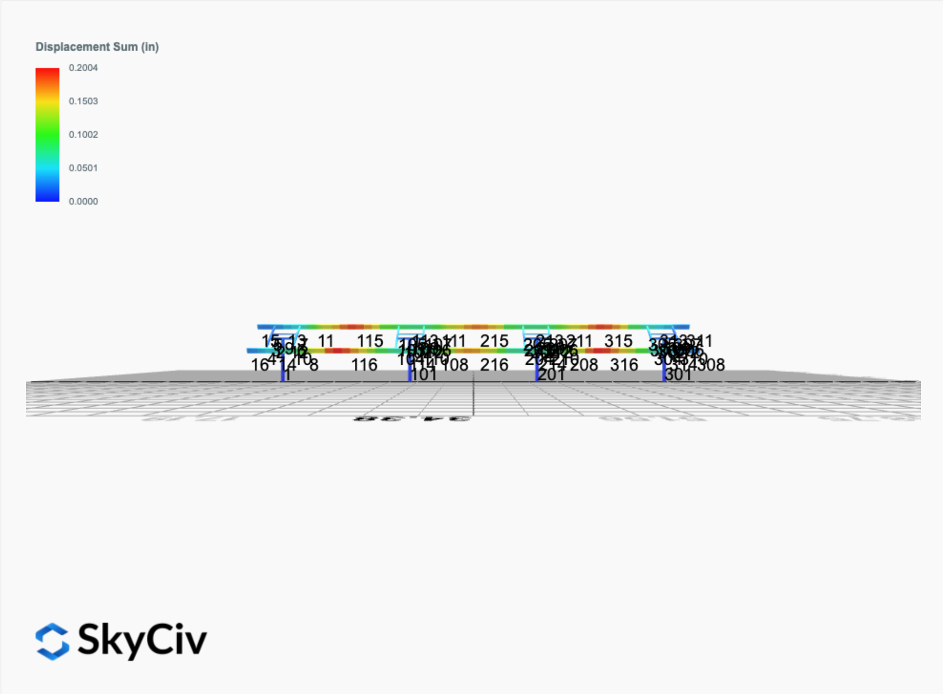


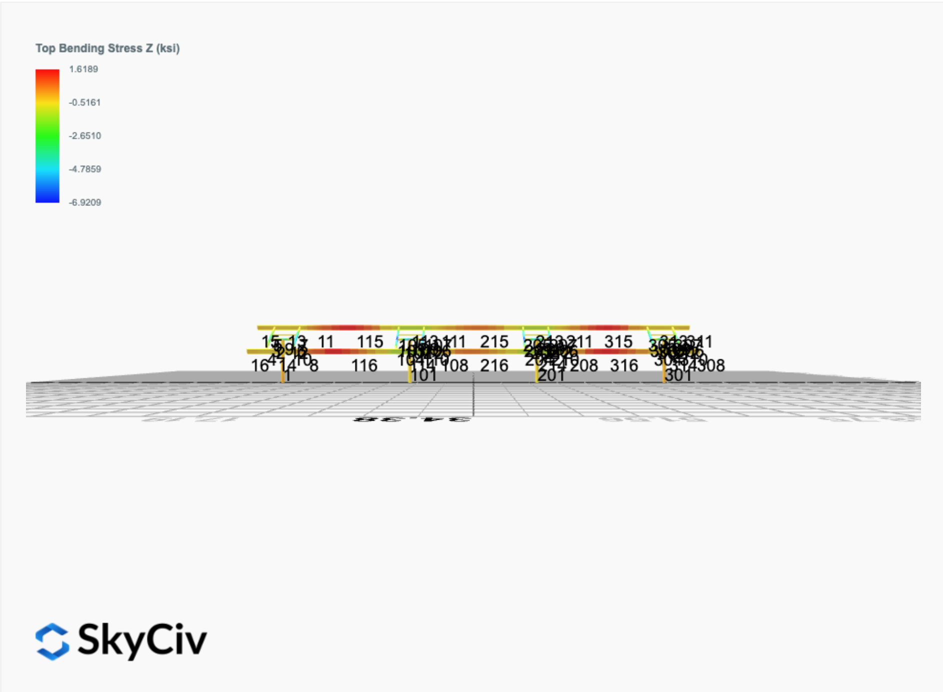

Displacement Sum (in)
0.1724
0.1293
0.0862
0.0431
0.0000


Top Bending Stress Z (ksi)
1.2230
-0.4577
-2.1384
-3.8191
-5.4998

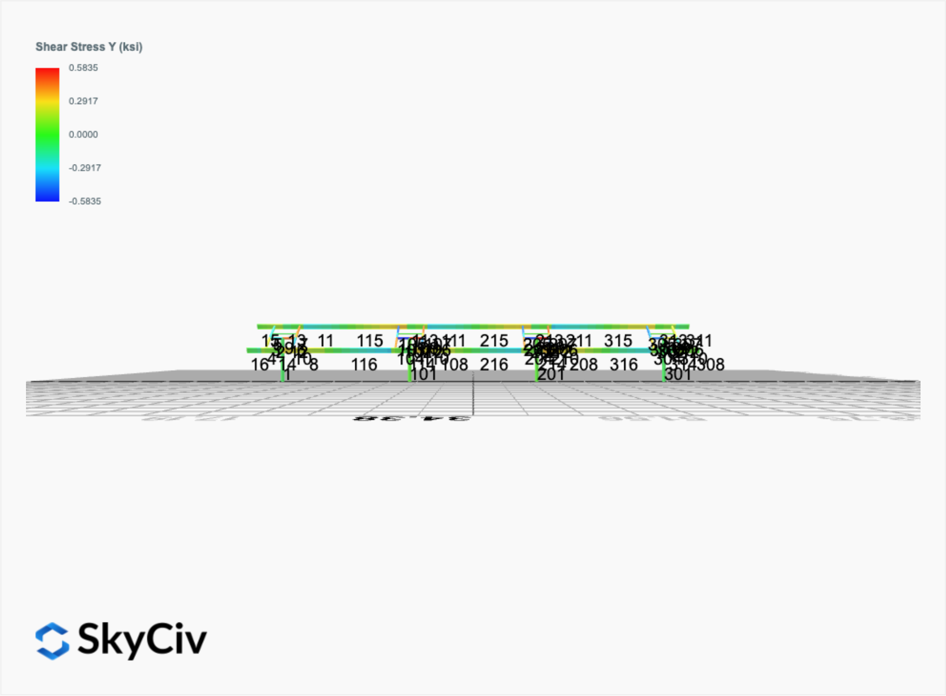

Top Bending Stress Y (ksi)
6.3602
3.1731
-0.0140
-3.2011
-6.3881

FEM Results (Envelope Worst Case for each member)

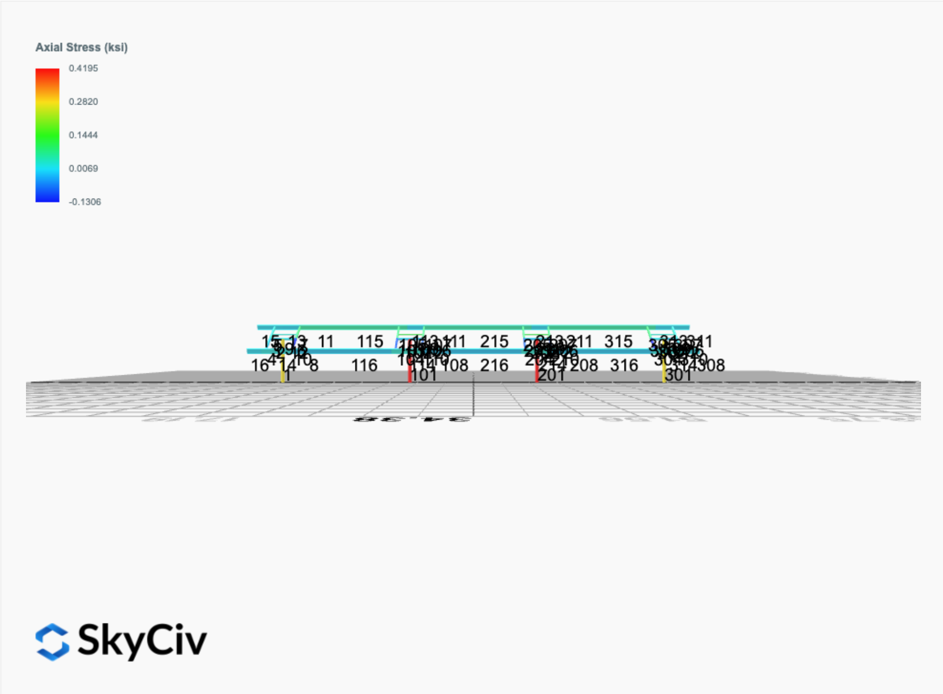




Top Bending Stress Y (ksi)
6.5580
3.2723
-0.0133
-3.2990
-6.5847
SkyCiv



Shear Stress Y (ksi)
0.5835
0.2917
0.0000
-0.2917
-0.5835
SkyCiv


Axial Stress (ksi)
0.4195
0.2820
0.1444
0.0069
-0.1306

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	0.0370	1.7153	0.1122	0.2038	-0.0423	-0.1952
ULS: 2. D + L	0.0370	1.7153	0.1122	0.2038	-0.0423	-0.1952
ULS: 3. D + (S or Lr or R)	0.0818	3.3064	0.2481	0.4510	-0.0938	-0.4647
ULS: 3. D + (S or Lr or R)	0.0370	1.7153	0.1122	0.2038	-0.0423	-0.1952
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0706	2.9087	0.2141	0.3892	-0.0809	-0.3973
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0370	1.7153	0.1122	0.2038	-0.0423	-0.1952
ULS: 5b. D + 0.7E	0.0370	1.7153	0.1122	0.2038	-0.0423	-0.1952
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0706	2.9087	0.2141	0.3892	-0.0809	-0.3973
ULS: 8. 0.6D + 0.7E	0.0222	1.0292	0.0673	0.1223	-0.0254	-0.1171
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7638	4.7826	0.4481	0.7813	-0.4770	12.4558
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7638	4.7826	0.4481	0.7813	-0.4770	12.4558
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5787	-0.9122	-0.1710	-0.2825	0.3245	-10.7323
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3511	-0.4913	-0.1640	-0.2693	0.3242	-15.8411
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2800	5.2091	0.4661	0.8224	-0.4070	9.0910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2800	5.2091	0.4661	0.8224	-0.4070	9.0910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2269	0.9380	0.0017	0.0245	0.1942	-8.3001
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0562	1.2537	0.0070	0.0344	0.1940	-12.1317
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3136	4.0158	0.3641	0.6369	-0.3684	9.2931
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3136	4.0158	0.3641	0.6369	-0.3684	9.2931
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1933	-0.2553	-0.1002	-0.1609	0.2328	-8.0980
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0226	0.0603	-0.0950	-0.1511	0.2326	-11.9296
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7786	4.0965	0.4033	0.6998	-0.4601	12.5339
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7786	4.0965	0.4033	0.6998	-0.4601	12.5339
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5639	-1.5984	-0.2159	-0.3640	0.3414	-10.6542
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3363	-1.1775	-0.2089	-0.3509	0.3412	-15.7630

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	7.9666
Shear X	-3.0013
Shear Z	0.7657
Moment X	1.3368
Moment Y (Twist)	0.8041
Moment Z	26.7160

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	5.2091
Shear X	-1.7786
Shear Z	0.4661
Moment X	0.8224
Moment Y (Twist)	0.4770
Moment Z	15.8411

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	-0.0370	2.3394	-0.0112	-0.0207	0.0132	0.2546
ULS: 2. D + L	-0.0370	2.3394	-0.0112	-0.0207	0.0132	0.2546
ULS: 3. D + (S or Lr or R)	-0.0818	4.6853	-0.0247	-0.0457	0.0293	0.5319
ULS: 3. D + (S or Lr or R)	-0.0370	2.3394	-0.0112	-0.0207	0.0132	0.2546
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0706	4.0989	-0.0213	-0.0394	0.0253	0.4625
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0370	2.3394	-0.0112	-0.0207	0.0132	0.2546
ULS: 5b. D + 0.7E	-0.0370	2.3394	-0.0112	-0.0207	0.0132	0.2546

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0706	4.0989	-0.0213	-0.0394	0.0253	0.4625
ULS: 8. 0.6D + 0.7E	-0.0222	1.4036	-0.0067	-0.0124	0.0079	0.1527
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6768	6.9634	-0.0230	-0.0455	0.0103	18.1594
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.6768	6.9634	-0.0230	-0.0455	0.0103	18.1594
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2275	-1.6255	0.0010	0.0039	0.0126	-14.5470
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8207	-0.9477	-0.0227	-0.0368	0.0495	-20.8324
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0504	7.5668	-0.0301	-0.0581	0.0230	13.8912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0504	7.5668	-0.0301	-0.0581	0.0230	13.8912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6277	1.1252	-0.0122	-0.0210	0.0248	-10.6386
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3227	1.6335	-0.0300	-0.0515	0.0525	-15.3527
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0168	5.8074	-0.0200	-0.0393	0.0110	13.6832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0168	5.8074	-0.0200	-0.0393	0.0110	13.6832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6614	-0.6343	-0.0021	-0.0023	0.0127	-10.8466
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3563	-0.1259	-0.0199	-0.0327	0.0404	-15.5607
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6620	6.0276	-0.0185	-0.0372	0.0050	18.0576
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.6620	6.0276	-0.0185	-0.0372	0.0050	18.0576
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2423	-2.5612	0.0054	0.0121	0.0073	-14.6488
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8355	-1.8834	-0.0183	-0.0285	0.0442	-20.9343

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.6863
Shear X	-4.4654
Shear Z	-0.0467
Moment X	-0.0847
Moment Y (Twist)	0.0870
Moment Z	35.1588

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.5668
Shear X	-2.6768
Shear Z	-0.0301
Moment X	-0.0581
Moment Y (Twist)	0.0525
Moment Z	20.9343

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	-0.0370	2.3394	0.0112	0.0207	-0.0132	0.2546
ULS: 2. D + L	-0.0370	2.3394	0.0112	0.0207	-0.0132	0.2546
ULS: 3. D + (S or Lr or R)	-0.0818	4.6853	0.0247	0.0457	-0.0292	0.5319
ULS: 3. D + (S or Lr or R)	-0.0370	2.3394	0.0112	0.0207	-0.0132	0.2546
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0706	4.0989	0.0213	0.0394	-0.0252	0.4625
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0370	2.3394	0.0112	0.0207	-0.0132	0.2546
ULS: 5b. D + 0.7E	-0.0370	2.3394	0.0112	0.0207	-0.0132	0.2546
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0706	4.0989	0.0213	0.0394	-0.0252	0.4625
ULS: 8. 0.6D + 0.7E	-0.0222	1.4036	0.0067	0.0124	-0.0079	0.1527
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6768	6.9634	0.0230	0.0455	-0.0102	18.1594
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.6768	6.9634	0.0230	0.0455	-0.0102	18.1594
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2275	-1.6255	-0.0010	-0.0039	-0.0126	-14.5470
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.8207	-0.9477	0.0227	0.0368	-0.0495	-20.8324
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0504	7.5668	0.0302	0.0580	-0.0230	13.8912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0504	7.5668	0.0302	0.0580	-0.0230	13.8912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6277	1.1252	0.0122	0.0210	-0.0247	-10.6386
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3227	1.6335	0.0300	0.0515	-0.0524	-15.3527

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0168	5.8074	0.0200	0.0393	-0.0110	13.6832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0168	5.8074	0.0200	0.0393	-0.0110	13.6832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6614	-0.6343	0.0021	0.0023	-0.0127	-10.8466
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3563	-0.1259	0.0199	0.0327	-0.0404	-15.5607
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6620	6.0276	0.0185	0.0372	-0.0050	18.0576
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.6620	6.0276	0.0185	0.0372	-0.0050	18.0576
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2423	-2.5612	-0.0054	-0.0121	-0.0073	-14.6488
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.8355	-1.8834	0.0183	0.0285	-0.0442	-20.9343

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.6863
Shear X	-4.4654
Shear Z	0.0467
Moment X	0.0845
Moment Y (Twist)	0.0869
Moment Z	35.1589

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.5668
Shear X	-2.6768
Shear Z	0.0302
Moment X	0.0580
Moment Y (Twist)	0.0524
Moment Z	20.9343

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	0.0370	1.7153	-0.1122	-0.2038	0.0423	-0.1952
ULS: 2. D + L	0.0370	1.7153	-0.1122	-0.2038	0.0423	-0.1952
ULS: 3. D + (S or Lr or R)	0.0818	3.3064	-0.2481	-0.4511	0.0938	-0.4647
ULS: 3. D + (S or Lr or R)	0.0370	1.7153	-0.1122	-0.2038	0.0423	-0.1952
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0706	2.9087	-0.2141	-0.3893	0.0810	-0.3973
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0370	1.7153	-0.1122	-0.2038	0.0423	-0.1952
ULS: 5b. D + 0.7E	0.0370	1.7153	-0.1122	-0.2038	0.0423	-0.1952
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0706	2.9087	-0.2141	-0.3893	0.0810	-0.3973
ULS: 8. 0.6D + 0.7E	0.0222	1.0292	-0.0673	-0.1223	0.0254	-0.1171
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7638	4.7826	-0.4481	-0.7813	0.4771	12.4559
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7638	4.7826	-0.4481	-0.7813	0.4771	12.4559
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5787	-0.9122	0.1710	0.2825	-0.3245	-10.7323
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3511	-0.4913	0.1640	0.2693	-0.3242	-15.8411
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2800	5.2091	-0.4661	-0.8224	0.4070	9.0910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2800	5.2091	-0.4661	-0.8224	0.4070	9.0910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2269	0.9380	-0.0017	-0.0246	-0.1941	-8.3001
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0562	1.2537	-0.0070	-0.0344	-0.1939	-12.1317
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3136	4.0158	-0.3641	-0.6370	0.3684	9.2931
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3136	4.0158	-0.3641	-0.6370	0.3684	9.2931
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1933	-0.2554	0.1002	0.1609	-0.2328	-8.0980
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0226	0.0603	0.0950	0.1510	-0.2326	-11.9296
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7786	4.0965	-0.4033	-0.6998	0.4601	12.5339
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7786	4.0965	-0.4033	-0.6998	0.4601	12.5339
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5639	-1.5984	0.2159	0.3640	-0.3414	-10.6542
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3363	-1.1775	0.2089	0.3508	-0.3411	-15.7630

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	7.9666
Shear X	-3.0013
Shear Z	-0.7657
Moment X	-1.3370
Moment Y (Twist)	0.8045
Moment Z	26.7167

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	5.2091
Shear X	-1.7786
Shear Z	-0.4661
Moment X	-0.8224
Moment Y (Twist)	0.4771
Moment Z	15.8411

Project Details

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

Design Input Information

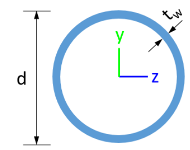
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

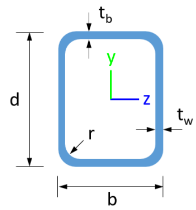
Design Materials

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

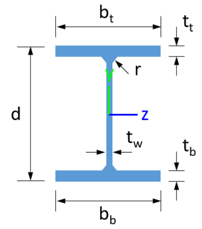
Section Dimensions



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



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



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

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24

7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	14.19	14.19	6.76	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.20,2.04,1.18,1.18,1.14,1.16,1.17,1.17,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.70,1.70,1.67,1.67,1.65,1.72,1.67,1.67,1.65,1.83,1.67,1.67,1.71,1.68,1.68,1.68,1.62,1.72,1.67,1.67,1.66,1.17	300	200	1
5	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.70,1.55,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.20,1.11,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.58,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.20,1.20,1.20,1.20,1.20,1.19,1.19,1.18,1.78,1.19,1.19,1.18,1.14,1.19,1.19,1.25,1.27,1.19,1.19,1.17,1.99,1.19,1.19,1.18,1.04	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.65,1.71,1.67,1.67,1.66,2.00,1.67,1.67,1.70,1.68,1.68,1.68,1.63,1.72,1.67,1.67,1.66,1.55	300	200	1
11	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.24,1.24,1.26,1.33,1.24,1.24,1.25,1.31,1.23,1.23,1.16,1.24,1.24,1.24,1.28,1.35,1.24,1.24,1.25,1.31	300	200	1
12	6	4.20	4.20	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.76,1.78,1.76,1.79,1.77,1.76,1.56,1.56,1.40,1.40,1.54,1.54,1.46,1.41,1.65,1.65,2.69,2.35,1.59,1.59,1.38,1.39,1.54,1.54,1.49,1.41	300	200	1
14	20	4.88	4.00	7.50	1.95,1.98,1.95,2.01,1.96,1.95,2.27,2.27,2.63,2.14,2.29,2.29,2.50,2.58,2.17,2.17,1.38,1.52,2.22,2.22,2.92,1.80,2.30,2.30,2.45,2.92	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.35,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.34,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
101	7	14.19	14.19	6.76	-	300	200	1
102	6	4.20	4.20	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.25,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.55,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.63	300	200	1
105	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.74,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.39,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.44,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	30	20	1

						0	0	
108	20	1.33	1.33	2.05	2.35,2.35,2.35,2.35,2.35,2.31,2.31,2.29,1.15,2.31,2.31,2.30,1.02,2.33,2.33,2.10,2.07,2.32,2.32,2.27,1.31,2.31,2.31,2.30,1.11	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.40,1.67,1.67,1.70,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.62	300	200	1
111	20	1.33	1.33	2.05	2.11,2.11,2.11,2.11,2.11,2.11,2.03,2.03,1.65,1.47,1.99,1.99,1.76,1.52,2.07,2.07,1.62,1.00,2.06,2.06,1.53,1.41,1.96,1.96,1.81,1.54	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.09,1.16,1.08,1.08,1.09,1.12,1.07,1.07,1.04,1.00,1.08,1.08,1.11,1.24,1.08,1.08,1.08,1.11	300	200	1
114	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.10,1.06,1.06,1.07,1.04,1.06,1.06,1.05,1.07,1.06,1.06,1.07,3.93,1.07,1.07,1.07,1.04	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.11,1.09,1.13,1.13,1.11,1.10,1.13,1.13,1.28,2.05,1.13,1.13,1.10,1.08,1.12,1.12,1.12,1.10	300	200	1
116	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.19,1.15,1.18,1.18,1.18,2.27,1.17,1.17,1.14,1.13,1.18,1.18,1.19,1.07,1.18,1.18,1.18,1.99	300	200	1
201	7	14.19	14.19	6.76	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.39,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.40,1.67,1.67,1.70,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.62	300	200	1
205	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.43,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.25,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.74,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.02,2.03,2.02,2.03,2.03,2.02,2.08,2.08,2.09,1.04,2.08,2.08,2.08,1.17,2.07,2.07,1.76,1.60,2.08,2.08,2.10,1.19,2.08,2.08,2.08,1.30	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.55,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.63	300	200	1
211	20	1.33	1.33	2.05	1.80,1.80,1.80,1.80,1.80,1.80,1.56,1.56,1.42,1.32,1.55,1.55,1.46,1.35,1.64,1.64,2.24,1.12,1.58,1.58,1.36,1.29,1.54,1.54,1.48,1.37	300	200	1
212	6	4.20	4.20	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.09,1.16,1.08,1.08,1.09,1.12,1.07,1.07,1.04,1.00,1.08,1.08,1.11,1.24,1.08,1.08,1.08,1.11	300	200	1
214	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.10,1.06,1.06,1.07,1.04,1.06,1.06,1.05,1.07,1.06,1.06,1.07,3.95,1.07,1.07,1.07,1.04	300	200	1
215	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.14,1.12,1.11,1.14,1.14,1.13,1.11,1.15,1.15,2.01,1.01,1.14,1.14,1.11,1.10,1.14,1.14,1.13,1.11	300	200	1
216	20	6.63	6.63	10.20	1.18,1.19,1.18,1.19,1.19,1.18,1.19,1.19,1.20,1.06,1.19,1.19,1.20,1.05,1.19,1.19,1.16,1.15,1.19,1.19,1.21,1.09,1.19,1.19,1.20,1.40	300	200	1
301	7	14.19	14.19	6.76	-	300	200	1

302	6	4.20	4.20	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.20,1.12,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.65,1.72,1.67,1.67,1.66,2.00,1.67,1.67,1.70,1.68,1.68,1.68,1.63,1.72,1.67,1.67,1.66,1.55	300	200	1
305	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.58,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.20,2.04,1.18,1.18,1.14,1.16,1.17,1.17,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.70,1.53,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.34,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.70,1.70,1.67,1.67,1.65,1.72,1.67,1.67,1.65,1.83,1.67,1.67,1.71,1.68,1.68,1.68,1.62,1.72,1.67,1.67,1.66,1.17	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.35,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.76,1.78,1.76,1.79,1.77,1.76,1.56,1.56,1.40,1.40,1.54,1.54,1.46,1.41,1.65,1.65,2.70,2.35,1.58,1.58,1.38,1.39,1.54,1.54,1.49,1.41	300	200	1
314	20	4.88	4.00	7.50	1.95,1.98,1.95,2.01,1.96,1.95,2.27,2.27,2.63,2.14,2.29,2.29,2.51,2.57,2.17,2.17,1.37,1.52,2.22,2.22,2.93,1.80,2.30,2.30,2.45,2.92	300	200	1
315	20	6.63	6.63	10.20	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.09,1.07,1.07,1.08,2.23,1.07,1.07,1.08,1.10,1.07,1.07,1.07,1.08	300	200	1
316	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.07,1.07,1.07,1.48,1.07,1.07,1.07,2.14,1.07,1.07,1.08,1.08,1.07,1.07,1.07,1.17,1.07,1.07,1.07,1.65	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	251.16	164.92	42.30	42.30	75.35	75.35
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	229.64	27.16	27.16	75.30	75.30
13	159.30	116.35	42.05	6.46	56.26	44.91
14	159.30	116.35	42.04	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	251.16	164.92	42.30	42.30	75.35	75.35
102	251.01	229.64	27.16	27.16	75.30	75.30

103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	30.58	6.46	56.26	44.91
114	159.30	116.35	31.80	6.46	56.26	44.91
115	159.30	75.13	20.81	6.46	56.26	44.91
116	159.30	75.13	20.66	6.46	56.26	44.91
201	251.16	164.92	42.30	42.30	75.35	75.35
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	229.64	27.16	27.16	75.30	75.30
213	159.30	116.35	30.58	6.46	56.26	44.91
214	159.30	116.35	31.77	6.46	56.26	44.91
215	159.30	75.13	19.41	6.46	56.26	44.91
216	159.30	75.13	20.19	6.46	56.26	44.91
301	251.16	164.92	42.30	42.30	75.35	75.35
302	251.01	229.64	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	137.23	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	137.23	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	42.03	6.46	56.26	44.91
314	159.30	116.35	42.01	6.46	56.26	44.91
315	159.30	75.13	20.64	6.46	56.26	44.91
316	159.30	75.13	20.67	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.048	0.632	0.090	0.039	0.010	0.643	#16	0.379	Not Required	Pass
2	0.002	0.169	0.088	0.041	0.018	0.258	#13	0.054	Not Required	Pass
3	0.003	0.311	0.012	0.030	0.004	0.324	#13	0.046	Not Required	Pass

4	0.002	0.312	0.047	0.031	0.010	0.359	#13	0.122	Not Required	Pass
5	0.002	0.192	0.011	0.031	0.004	0.203	#13	0.076	Not Required	Pass
6	0.005	0.454	0.066	0.047	0.018	0.504	#13	0.046	Not Required	Pass
7	0.005	0.281	0.090	0.045	0.022	0.300	#13	0.076	Not Required	Pass
8	0.003	0.112	0.098	0.026	0.010	0.151	#13	0.102	Not Required	Pass
9	0.003	0.043	0.054	0.003	0.004	0.093	#13	0.206	Not Required	Pass
10	0.006	0.423	0.085	0.042	0.019	0.437	#13	0.082	Not Required	Pass
11	0.005	0.106	0.100	0.028	0.010	0.137	#13	0.102	Not Required	Pass
12	0.002	0.310	0.118	0.062	0.022	0.428	#13	0.174	Not Required	Pass
13	0.006	0.049	0.244	0.037	0.013	0.257	#24	0.306	Not Required	Pass
14	0.003	0.062	0.242	0.035	0.013	0.254	#24	0.204	Not Required	Pass
15	0.000	0.003	0.006	0.005	0.002	0.008	#21	Not Required	Not Required	Pass
16	0.000	0.003	0.006	0.005	0.002	0.008	#21	Not Required	Not Required	Pass
101	0.071	0.831	0.006	0.059	0.001	0.839	#32	0.379	Not Required	Pass
102	0.002	0.364	0.161	0.077	0.029	0.525	#13	0.116	Not Required	Pass
103	0.005	0.553	0.034	0.055	0.005	0.577	#13	0.046	Not Required	Pass
104	0.005	0.575	0.088	0.058	0.019	0.613	#13	0.082	Not Required	Pass
105	0.005	0.342	0.092	0.055	0.024	0.358	#13	0.076	Not Required	Pass
106	0.005	0.556	0.032	0.056	0.005	0.572	#13	0.046	Not Required	Pass
107	0.005	0.345	0.085	0.055	0.022	0.359	#13	0.076	Not Required	Pass
108	0.004	0.041	0.088	0.031	0.010	0.121	#21	0.102	Not Required	Pass
109	0.008	0.050	0.034	0.001	0.000	0.083	#13	0.206	Not Required	Pass
110	0.005	0.558	0.084	0.056	0.018	0.594	#13	0.082	Not Required	Pass
111	0.004	0.051	0.090	0.031	0.010	0.111	#21	0.102	Not Required	Pass
112	0.002	0.357	0.160	0.076	0.030	0.517	#13	0.036	Not Required	Pass
113	0.006	0.151	0.249	0.044	0.013	0.353	#21	0.306	Not Required	Pass
114	0.006	0.193	0.249	0.046	0.013	0.379	#21	0.306	Not Required	Pass
115	0.009	0.302	0.127	0.035	0.010	0.382	#13	0.507	Not Required	Pass
116	0.005	0.289	0.129	0.037	0.011	0.362	#13	0.507	Not Required	Pass
201	0.071	0.831	0.006	0.059	0.001	0.839	#32	0.379	Not Required	Pass
202	0.002	0.357	0.160	0.076	0.030	0.517	#13	0.036	Not Required	Pass
203	0.005	0.556	0.032	0.056	0.005	0.572	#13	0.046	Not Required	Pass
204	0.005	0.558	0.084	0.056	0.018	0.594	#13	0.082	Not Required	Pass
205	0.005	0.345	0.085	0.055	0.022	0.359	#13	0.076	Not Required	Pass
206	0.005	0.553	0.034	0.055	0.005	0.577	#13	0.046	Not Required	Pass
207	0.005	0.342	0.092	0.055	0.024	0.358	#13	0.076	Not Required	Pass
208	0.003	0.055	0.104	0.037	0.011	0.122	#21	0.102	Not Required	Pass
209	0.008	0.050	0.034	0.001	0.000	0.083	#13	0.206	Not Required	Pass
210	0.005	0.575	0.088	0.058	0.019	0.613	#13	0.082	Not Required	Pass
211	0.005	0.074	0.104	0.035	0.010	0.109	#21	0.102	Not Required	Pass
212	0.002	0.364	0.161	0.077	0.029	0.525	#13	0.116	Not Required	Pass
213	0.006	0.151	0.249	0.044	0.013	0.353	#21	0.306	Not Required	Pass
214	0.006	0.193	0.249	0.046	0.013	0.379	#21	0.306	Not Required	Pass
215	0.008	0.204	0.128	0.031	0.010	0.291	#21	0.507	Not Required	Pass
216	0.005	0.153	0.127	0.031	0.010	0.253	#21	0.507	Not Required	Pass
301	0.048	0.632	0.090	0.039	0.010	0.643	#16	0.379	Not Required	Pass
302	0.002	0.310	0.118	0.062	0.022	0.428	#13	0.174	Not Required	Pass
303	0.005	0.454	0.066	0.047	0.018	0.504	#13	0.046	Not Required	Pass
304	0.006	0.423	0.085	0.042	0.019	0.437	#13	0.082	Not Required	Pass
305	0.005	0.281	0.090	0.045	0.022	0.300	#13	0.076	Not Required	Pass
306	0.003	0.311	0.012	0.030	0.004	0.324	#13	0.046	Not Required	Pass
307	0.002	0.192	0.011	0.031	0.004	0.203	#13	0.076	Not Required	Pass
308	0.000	0.003	0.006	0.005	0.002	0.008	#21	Not Required	Not Required	Pass
309	0.003	0.043	0.054	0.003	0.004	0.093	#13	0.206	Not Required	Pass

309	0.005	0.045	0.054	0.005	0.004	0.095	#13	0.206	Not Required	Pass
310	0.002	0.312	0.047	0.031	0.010	0.359	#13	0.122	Not Required	Pass
311	0.000	0.003	0.006	0.005	0.002	0.008	#21	Not Required	Not Required	Pass
312	0.002	0.169	0.088	0.041	0.018	0.258	#13	0.054	Not Required	Pass
313	0.006	0.049	0.244	0.037	0.013	0.257	#24	0.204	Not Required	Pass
314	0.003	0.062	0.242	0.035	0.013	0.254	#24	0.306	Not Required	Pass
315	0.009	0.322	0.128	0.028	0.010	0.397	#13	0.507	Not Required	Pass
316	0.005	0.315	0.127	0.027	0.010	0.393	#13	0.507	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

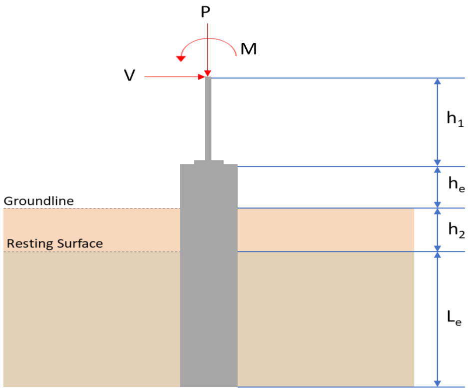
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 7.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.107	7.845
V_x (kip)	-1.782	-3.004
V_z (kip)	0.560	0.918
M_x (kipft)	0.937	1.519
M_z (kipft)	15.704	26.471

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.782\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.594\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.704 \text{ kipft}) + ((-1.782 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.2347 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.6041 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.56 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.18667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.937 \text{ kipft}) + ((0.56 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.31233 \text{ kipft/ft}$$

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:
$L_{e,z} = 5.0385 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6041 \text{ ft}), (5.0385 \text{ ft})]$$

$$L_{e,req} = 6.604 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.604 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.88053$$

Status: **PASS**
Ratio: **0.880**

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

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

$$q = \frac{(5.107 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.72249\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.72249\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.36125$$

Status: **PASS**
Ratio: **0.360**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.594\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2347\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2347\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (5.2347\ \mathrm{kipft/ft})) + (4 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2262\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.2347\ \mathrm{kipft/ft})) + (3 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (5.2347\ \mathrm{kipft/ft})) + (2 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.17681\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.2347\ \mathrm{kipft/ft})) + ((-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0077\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2262\ \mathrm{ft})}{2}$$

$$p_a = 0.39197\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17681\ \mathrm{kip/ft^2}\right)}{\left(0.39197\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.45109$$

Status: **PASS**
Ratio: **0.450**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.0077\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.89576$$

Status: PASS
Ratio: 0.900

Considering z-direction:

$H_o = 0.18667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.31233\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31233\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.31233\ \mathrm{kipft/ft})) + (4 \times (0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.4683\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.31233\ \mathrm{kipft/ft})) + (3 \times (0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.31233\ \mathrm{kipft/ft})) + (2 \times (0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.16641\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.31233\ \mathrm{kipft/ft})) + ((0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.33924\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.4683\ \mathrm{ft})}{2}$$

$$p_a = 0.41012\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.16641\ \mathrm{kip/ft^2})}{(0.41012\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.40576$$

Status: PASS
Ratio: 0.410

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

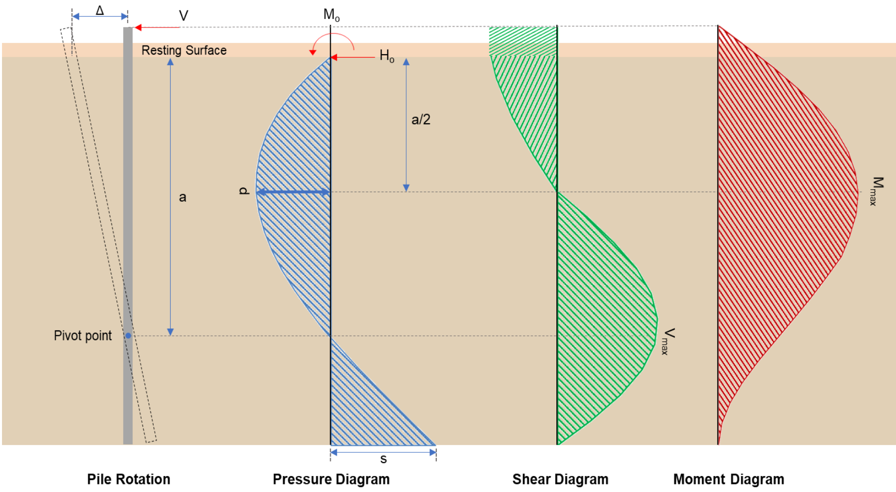
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.33924\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.30155$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.004\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.0013\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.471\ \mathrm{kipft}) + ((-3.004\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 8.8237\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.8237\ \mathrm{kipft/ft})}{(-1.0013\ \mathrm{kip/ft})}$$

$$E = 8.8119\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.8237\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-1.0013\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (8.8237\ \mathrm{kipft/ft})) + (4 \times (-1.0013\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2263\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.0013\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.8119\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2263\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.8119\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2263\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2273 \text{ kip}$$

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

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

$$M_{max} = ((-1.0013 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.8119 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.8119 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.8119 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 28.818 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.918 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.306 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.519 \text{ kipft}) + ((0.918 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.50633 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.50633 \text{ kipft/ft})}{(0.306 \text{ kip/ft})}$$

$$E = 1.6547 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.50633 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (0.306 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.50633 \text{ kipft/ft})) + (4 \times (0.306 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.4696 \text{ ft}$$

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

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

$$V_{max} = ((0.306 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.4696 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.4696 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.97758 \text{ kip}$$

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

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

$$M_{max} = ((0.306 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(1.6547 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 3.0575 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.845 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.128 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.128 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** 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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(7.845\text{ kip})}{(1253.9\text{ kip})}$$ $$Ratio = 0.0062564$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\text{ in})$$ $$d = 28.8\text{ in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - 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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 7.845\text{ kip} \rightarrow 7845\text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(7845\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,a} = 75.77\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,b}$ - 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\text{ kip}), (75.77\text{ kip}), (204.04\text{ kip})\right]$$	

$$V_c = 75.77\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.77\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 74.061\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 8.2273\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.2273\ \mathrm{kip})}{(74.061\ \mathrm{kip})}$$

$$Ratio = 0.11109$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.97758\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.97758\ \mathrm{kip})}{(74.061\ \mathrm{kip})}$$

$$Ratio = 0.0132$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$S_m = 4580.4\ \text{in}^3$ $\lambda = 1$ - 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:** $M_{max} = 28.818\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(28.818\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.4646$$	Status: **PASS** Ratio: **0.460**
	Considering z-direction: $M_{max} = 3.0575\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(3.0575\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.049294$$	Status: **PASS** Ratio: **0.050**

REFERENCES	CALCULATIONS	RESULTS

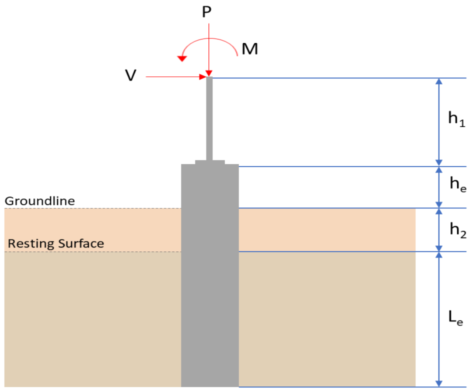
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 7.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.107	7.845
V_x (kip)	-1.782	-3.004
V_z (kip)	-0.560	-0.918
M_x (kipft)	-0.937	-1.519
M_z (kipft)	15.704	26.471

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.782\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.594\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.704\ \text{kipft}) + ((-1.782\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.2347\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.6041\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.56\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.18667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.937\ \text{kipft}) + ((-0.56\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.31233\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.863\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6041\ \text{ft}), (1.863\ \text{ft})]$$

$$L_{e,req} = 6.604\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.604\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.88053$$

Status: **PASS**
Ratio: **0.880**

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

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

$$q = \frac{(5.107\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.72249\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.72249\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.36125$$

Status: **PASS**
Ratio: **0.360**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.594\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2347\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2347\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (5.2347\ \mathrm{kipft/ft})) + (4 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2262\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.2347\ \mathrm{kipft/ft})) + (3 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (5.2347\ \mathrm{kipft/ft})) + (2 \times (-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.17681\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.2347\ \mathrm{kipft/ft})) + ((-0.594\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0077\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2262\ \mathrm{ft})}{2}$$

$$p_a = 0.39197\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17681\ \mathrm{kip/ft^2}\right)}{\left(0.39197\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.45109$$

Status: **PASS**
Ratio: **0.450**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0077\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89576$$

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = -0.18667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.31233\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31233\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.31233\ \mathrm{kipft/ft})) + (4 \times (-0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.4683\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.31233\ \mathrm{kipft/ft})) + (3 \times (-0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.31233\ \mathrm{kipft/ft})) + (2 \times (-0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.09787\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.31233\ \mathrm{kipft/ft})) + ((-0.18667\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = -0.12991\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.4683\ \mathrm{ft})}{2}$$

$$p_a = 0.41012\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.09787\ \mathrm{kip/ft^2}\right)}{\left(0.41012\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.23864$$

Status: **PASS**
Ratio: **-0.240**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

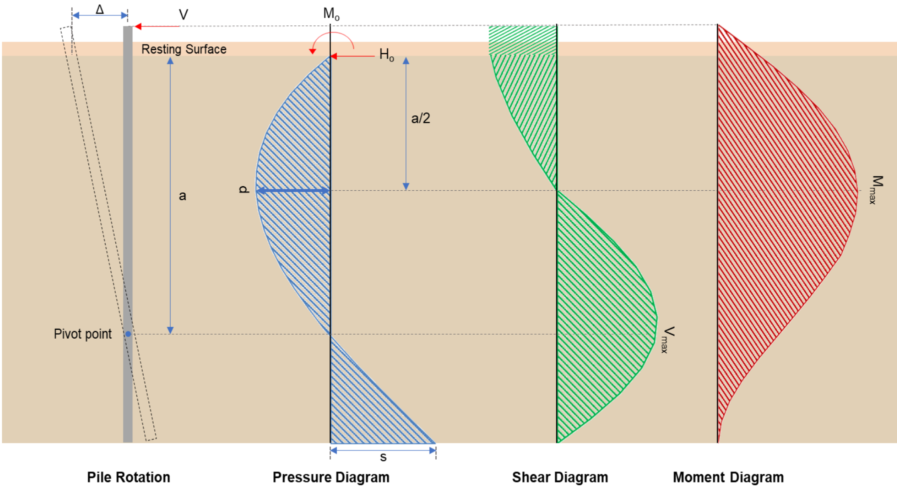
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.12991\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.11548$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.004\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.0013\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.471\ \mathrm{kipft}) + ((-3.004\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 8.8237\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.8237\ \mathrm{kipft/ft})}{(-1.0013\ \mathrm{kip/ft})}$$

$$E = 8.8119\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.8237\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-1.0013\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (8.8237\ \mathrm{kipft/ft})) + (4 \times (-1.0013\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2263\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.0013\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.8119\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2263\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.8119\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2263\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.2273 \text{ kip}$$

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

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

$$M_{max} = ((-1.0013 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.8119 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.8119 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.8119 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.2263 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 28.818 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.918 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.306 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.519 \text{ kipft}) + ((-0.918 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.50633 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.50633 \text{ kipft/ft})}{(-0.306 \text{ kip/ft})}$$

$$E = 1.6547 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.50633 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.306 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.50633 \text{ kipft/ft})) + (4 \times (-0.306 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.4696 \text{ ft}$$

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

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

$$V_{max} = ((-0.306 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4696 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4696 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.97758 \text{ kip}$$

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

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

$$M_{max} = ((-0.306 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(1.6547 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (1.6547 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4696 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 3.0575 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.845 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.128 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.128 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

$$Ratio = \frac{(7.845\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.0062564$$

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

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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 7.845\text{ kip} \rightarrow 7845\text{ lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(7845\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 75.77\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\text{ kip}), (75.77\text{ kip}), (204.04\text{ kip})\right]$$

$$V_c = 75.77 \text{ kip}$$

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

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

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

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

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

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

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

$$\phi V_n = (0.65) \times ((75.77 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.061 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.2273 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.2273 \text{ kip})}{(74.061 \text{ kip})}$$

$$Ratio = 0.11109$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.97758 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.97758 \text{ kip})}{(74.061 \text{ kip})}$$

$$Ratio = 0.0132$$

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

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:** $M_{max} = 28.818\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(28.818\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.4646$$	Status: **PASS** Ratio: **0.460**
	Considering z-direction: $M_{max} = 3.0575\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(3.0575\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.049294$$	Status: **PASS** Ratio: **0.050**

REFERENCES	CALCULATIONS	RESULTS

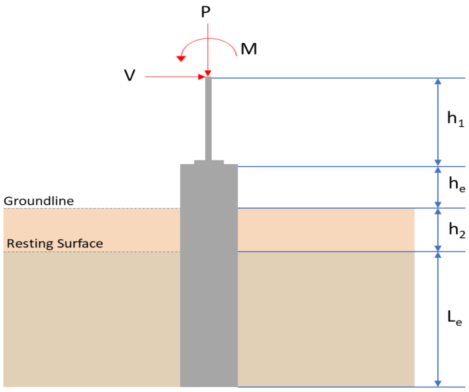
SkyCiv Foundation Design

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
$L = 7.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
$P\ (\mathrm{kip})$	7.416	11.504
$V_x\ (\mathrm{kip})$	-2.672	-4.457
$V_z\ (\mathrm{kip})$	-0.061	-0.092
$M_x\ (\mathrm{kipft})$	-0.109	-0.165
$M_z\ (\mathrm{kipft})$	21.070	35.378

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,

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

$$H_o = \frac{(-2.672\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.89067\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.07\ \text{kipft}) + ((-2.672\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.0233\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7876\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.061\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.020333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.109\ \text{kipft}) + ((-0.061\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.036333\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.2822\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7876\ \text{ft}), (1.2822\ \text{ft})]$$

$$L_{e,req} = 6.788\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.788\ \text{ft})}{(7.75\ \text{ft})}$$

$$Ratio = 0.87587$$

Status: **PASS**
Ratio: **0.880**

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

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

$$q = \frac{(7.416\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.0491 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.0491 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.52457$$

Status: **PASS**
Ratio: **0.520**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5833$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.89067 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.0233 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0233 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.89067 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (7.0233 \text{ kipft/ft})) + (4 \times (-0.89067 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4223 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.0233 \text{ kipft/ft})) + (3 \times (-0.89067 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (7.0233 \text{ kipft/ft})) + (2 \times (-0.89067 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.14725 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.0233 \text{ kipft/ft})) + ((-0.89067 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.121 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.4223 \text{ ft})}{2}$$

$$p_a = 0.40667 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.14725 \text{ kip/ft}^2)}{(0.40667 \text{ kip/ft}^2)}$$

$$Ratio = 0.36209$$

Status: **PASS**
Ratio: **0.360**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.121\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96433$$

Status: **PASS**
Ratio: **0.960**

Considering z-direction:

$H_o = -0.020333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.036333\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.036333\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.036333\ \mathrm{kipft/ft})) + (4 \times (-0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.6465\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.036333\ \mathrm{kipft/ft})) + (3 \times (-0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^2}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.036333\ \mathrm{kipft/ft})) + (2 \times (-0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = -0.010198\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.036333\ \mathrm{kipft/ft})) + ((-0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = -0.013325\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6465\ \mathrm{ft})}{2}$$

$$p_a = 0.42349\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.010198\ \mathrm{kip/ft^2}\right)}{\left(0.42349\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.024081$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

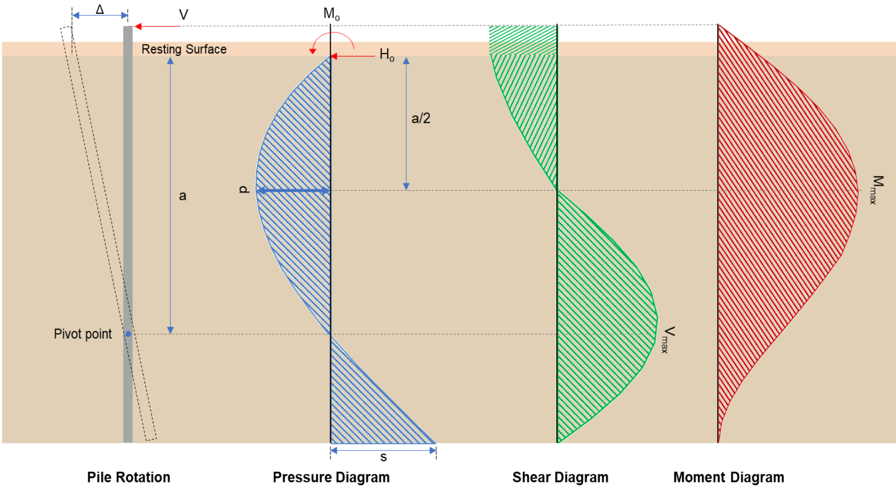
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(-0.013325\ \text{kip/ft}^2\right)}{\left(1.1625\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.011462$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.457\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -1.4857\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.378\ \text{kipft}) + ((-4.457\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.793\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.793\ \text{kipft/ft})}{(-1.4857\ \text{kip/ft})}$$

$$E = 7.9376\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.793\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-1.4857\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (11.793\ \text{kipft/ft})) + (4 \times (-1.4857\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.4213\ \text{ft}$$

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

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

$$V_{max} = ((-1.4857\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (7.9376\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.4213\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (7.9376\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.4213\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.021 \text{ kip}$$

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

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

$$M_{max} = ((-1.4857 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(7.9376 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (7.9376 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (7.9376 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 39.593 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.092 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.030667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.165 \text{ kipft}) + ((-0.092 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.055 \text{ kipft/ft})}{(-0.030667 \text{ kip/ft})}$$

$$E = 1.7935 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.055 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.030667 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (0.055 \text{ kipft/ft})) + (4 \times (-0.030667 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6461 \text{ ft}$$

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

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

$$V_{max} = ((-0.030667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.6461 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.6461 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.099687 \text{ kip}$$

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

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

$$M_{max} = ((-0.030667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(1.7935 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.32326 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.504 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.014 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.504\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.0091745$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 11.504\ \mathrm{kip} \rightarrow 11504\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11504\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 76.391\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (76.391\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 76.391 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.391 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.465 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.021 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.021 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.148$$

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

Considering z-direction:

$V_{max} = 0.099687 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.099687 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.0013387$$

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:** $M_{max} = 39.593 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(39.593 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.63832$$	Status: **PASS** Ratio: **0.640**
	Considering z-direction: $M_{max} = 0.32326 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.32326 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0052116$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

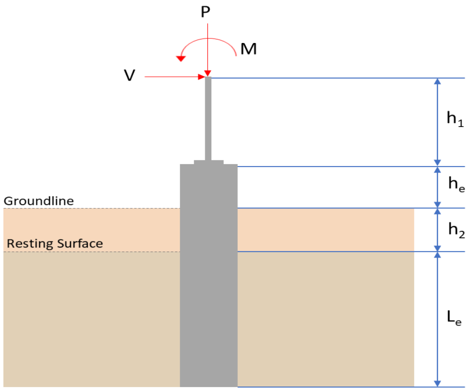
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round

$D = 36\ \text{in}$ - Pile diameter

$L = 7.75\ \text{ft}$ - Total pile length

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

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

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.416	11.504
V_x (kip)	-2.672	-4.457
V_z (kip)	0.061	0.092
M_x (kipft)	0.109	0.165
M_z (kipft)	21.070	35.378

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.672\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.89067\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.07\ \text{kipft}) + ((-2.672\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.0233\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7876\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.061\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.020333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.109\ \text{kipft}) + ((0.061\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.036333\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0386\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7876\ \text{ft}), (2.0386\ \text{ft})]$$

$$L_{e,req} = 6.788\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.788\ \text{ft})}{(7.75\ \text{ft})}$$

$$Ratio = 0.87587$$

Status: **PASS**
Ratio: **0.880**

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

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

$$q = \frac{(7.416\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.0491\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.0491\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.52457$$

Status: **PASS**
Ratio: **0.520**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.5833$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.89067\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.0233\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0233\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.89067\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (7.0233\ \text{kipft/ft})) + (4 \times (-0.89067\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.4223\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.0233\ \text{kipft/ft})) + (3 \times (-0.89067\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (7.0233\ \text{kipft/ft})) + (2 \times (-0.89067\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = 0.14725\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.0233\ \text{kipft/ft})) + ((-0.89067\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 1.121\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.4223\ \text{ft})}{2}$$

$$p_a = 0.40667\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.14725\ \text{kip/ft}^2\right)}{\left(0.40667\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.36209$$

Status: **PASS**
Ratio: **0.360**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.121\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96433$$

Status: PASS
Ratio: 0.960

Considering z-direction:

$H_o = 0.020333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.036333\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.036333\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.036333\ \mathrm{kipft/ft})) + (4 \times (0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.6465\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.036333\ \mathrm{kipft/ft})) + (3 \times (0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^2}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.036333\ \mathrm{kipft/ft})) + (2 \times (0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.017664\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.036333\ \mathrm{kipft/ft})) + ((0.020333\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 0.036131\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6465\ \mathrm{ft})}{2}$$

$$p_a = 0.42349\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.017664\ \mathrm{kip/ft^2}\right)}{\left(0.42349\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.041712$$

Status: PASS
Ratio: 0.040

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

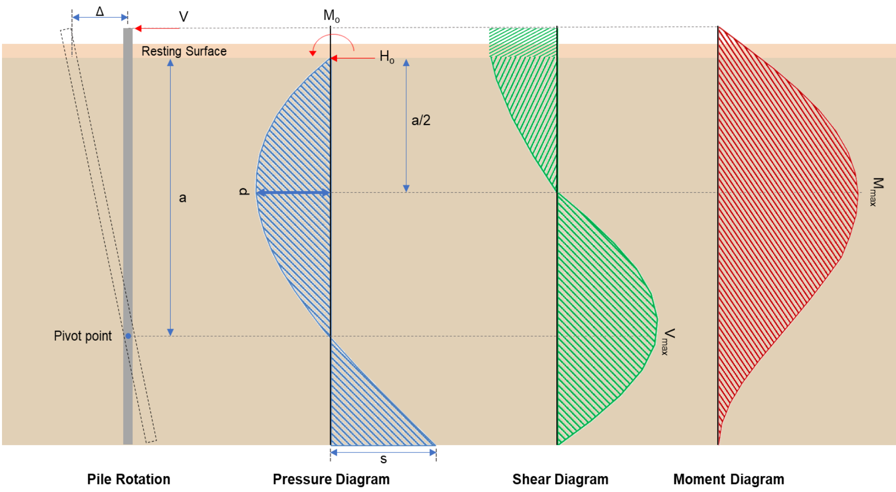
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(0.036131\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.03108$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.457\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.4857\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.378\ \mathrm{kipft}) + ((-4.457\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 11.793\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.793\ \mathrm{kipft/ft})}{(-1.4857\ \mathrm{kip/ft})}$$

$$E = 7.9376\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.793\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-1.4857\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (11.793\ \mathrm{kipft/ft})) + (4 \times (-1.4857\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.4213\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.4857\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (7.9376\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.4213\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (7.9376\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.4213\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.021 \text{ kip}$$

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

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

$$M_{max} = ((-1.4857 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(7.9376 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (7.9376 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (7.9376 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.4213 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 39.593 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.092 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.030667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.165 \text{ kipft}) + ((0.092 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.055 \text{ kipft/ft})}{(0.030667 \text{ kip/ft})}$$

$$E = 1.7935 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.055 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (0.030667 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (0.055 \text{ kipft/ft})) + (4 \times (0.030667 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6461 \text{ ft}$$

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

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

$$V_{max} = ((0.030667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.6461 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.6461 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.099687 \text{ kip}$$

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

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

$$M_{max} = ((0.030667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(1.7935 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.7935 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.6461 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.32326 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.504 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.014 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.504\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.0091745$$

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

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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}, P = 11.504\text{ kip} \rightarrow 11504\text{ lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(11504\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 76.391\text{ kip}$$

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

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

$$V_c = Min\left[(186.09\text{ kip}), (76.391\text{ kip}), (204.04\text{ kip})\right]$$

$$V_c = 76.391\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.391\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.465\ \text{kip}$$

Considering x-direction:

$V_{max} = 11.021\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.021\ \text{kip})}{(74.465\ \text{kip})}$$

$$Ratio = 0.148$$

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

Considering z-direction:

$V_{max} = 0.099687\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.099687\ \text{kip})}{(74.465\ \text{kip})}$$

$$Ratio = 0.0013387$$

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:** $M_{max} = 39.593\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(39.593\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.63832$$	Status: **PASS** Ratio: **0.640**
	Considering z-direction: $M_{max} = 0.32326\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.32326\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.0052116$$	Status: **PASS** Ratio: **0.010**