Your Project Calculations

Project Name: Roche_rev1

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Roche_rev1&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=HKsuET34wjsuDYjmXHkPfKtIrgcWXJGbSzuZKGFHrZcJerKNlwHDMGXqutkfAhQp

Array Specification

Product:	Beam
Unique ID:	5P-19.75-8TOP-HD-45-L-4Hx15W-DIGB
Duty Classification:	HD
Module Width:	41.10 in
Module Length:	74.00in
Number of Rows:	4
Number of Columns:	15
Total Number of Modules:	60
Desired Tilt Angle:	45
Front Edge Clearance:	6
Total Array Height at Tilt:	15.75 ft
Total Frame Length:	94.00 ft
Frame Weight:	5320 lbs
Array Dimensions N/S:	13.87 ft
Array Dimensions E/W:	93.75 ft
Rail Length:	166.40 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	10.90 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 15.00 ft Pile 2: 15.00 ft Pile 3: 15.00 ft Pile 4: 15.00 ft Pile 5: 15.00 ft
Foundation Volume:	19.635 y^3
Foundation Result:	FAILED Try increasing foundation size and/or type and re-running foundation design check on right panel.
Mount Twist:	0.859285 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Merna, WY 83115, USA
Wind Speed:	110 mph
Snow Load:	80 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.021993 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


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{"product_type":"Beam","project_id":"Roche_rev1","site_address":"Merna, WY 83115, USA","module_width":41.1,"module_length":74,"number_rows":"4","number_columns":15,"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":45,"ground_clearance":6,"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,"wind_speed_override":110,"snow_load_override":80,"direct_snow_load":false}
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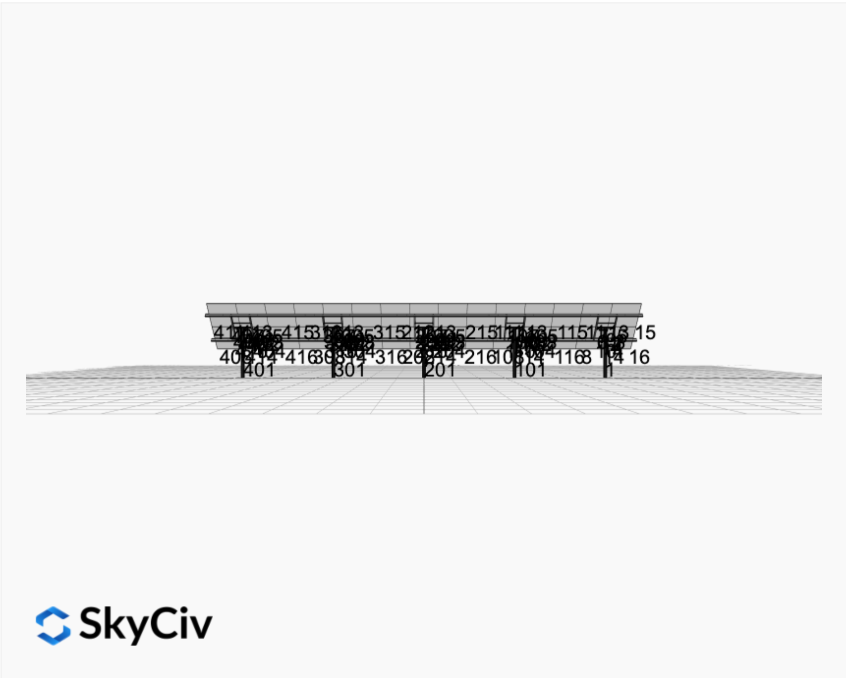
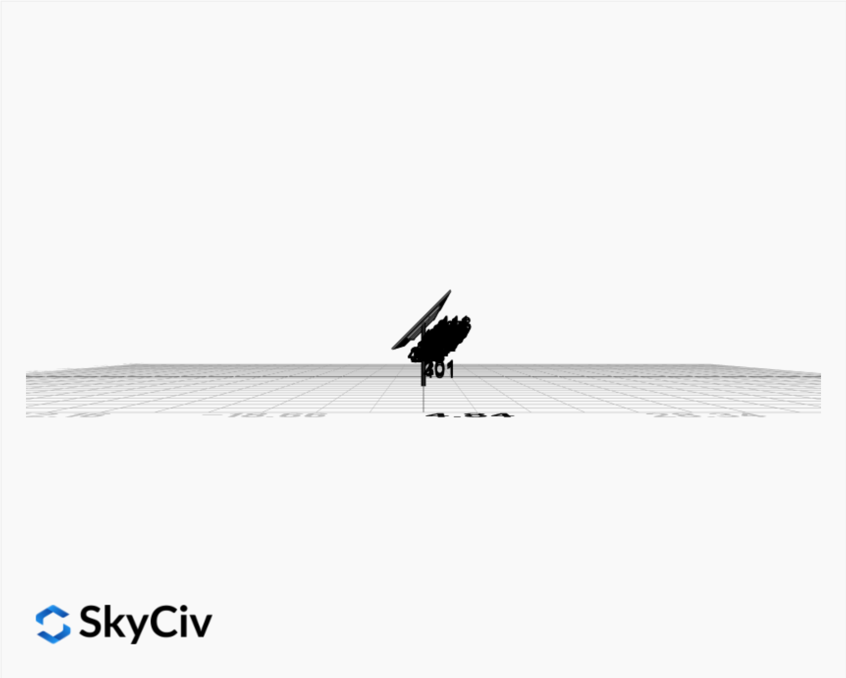
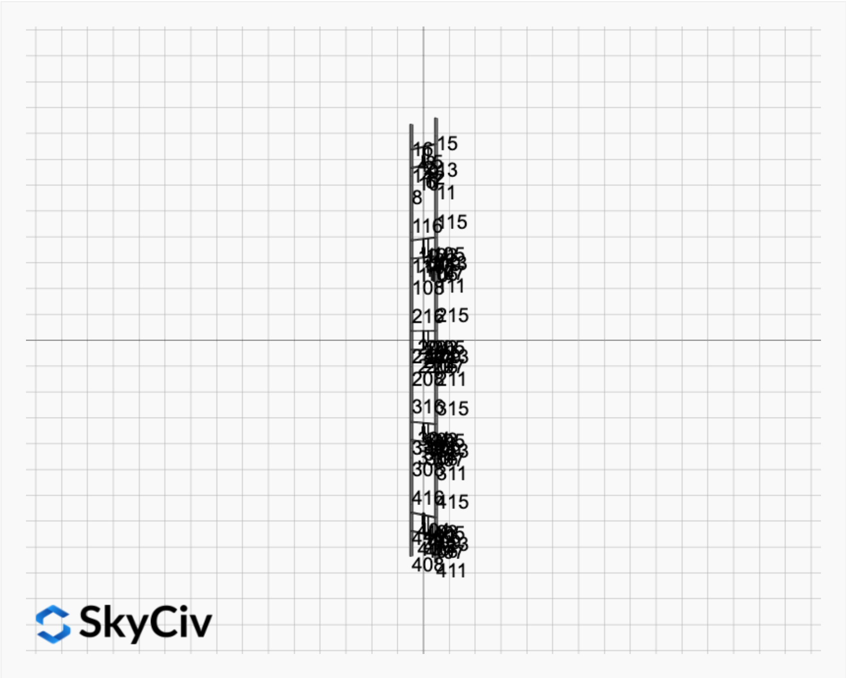
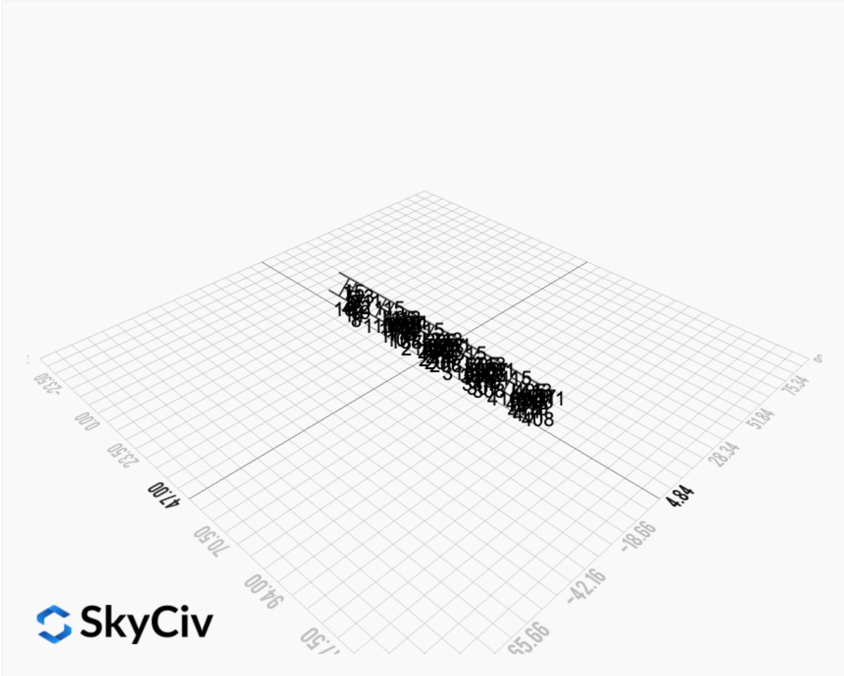
Design Notes:

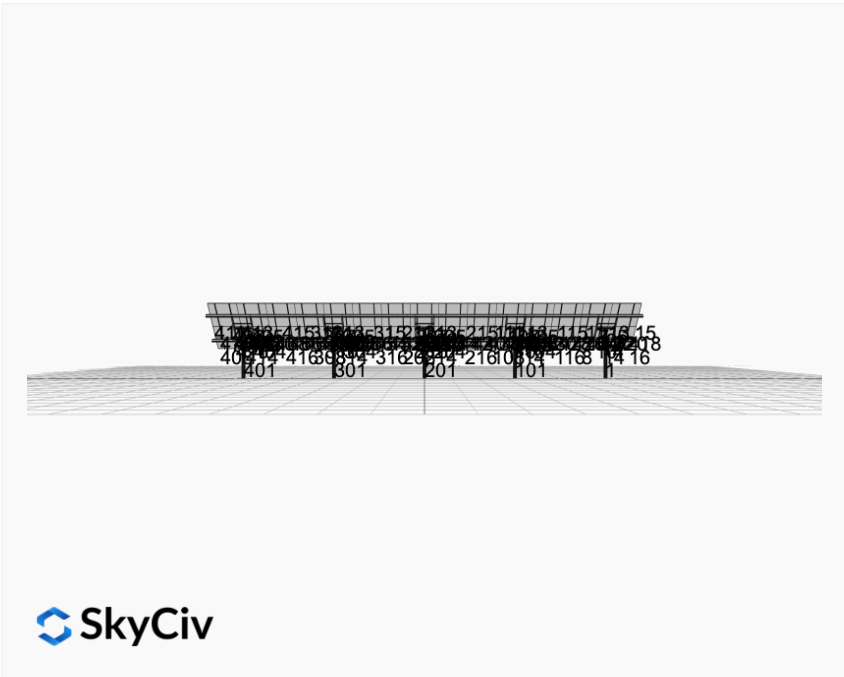
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



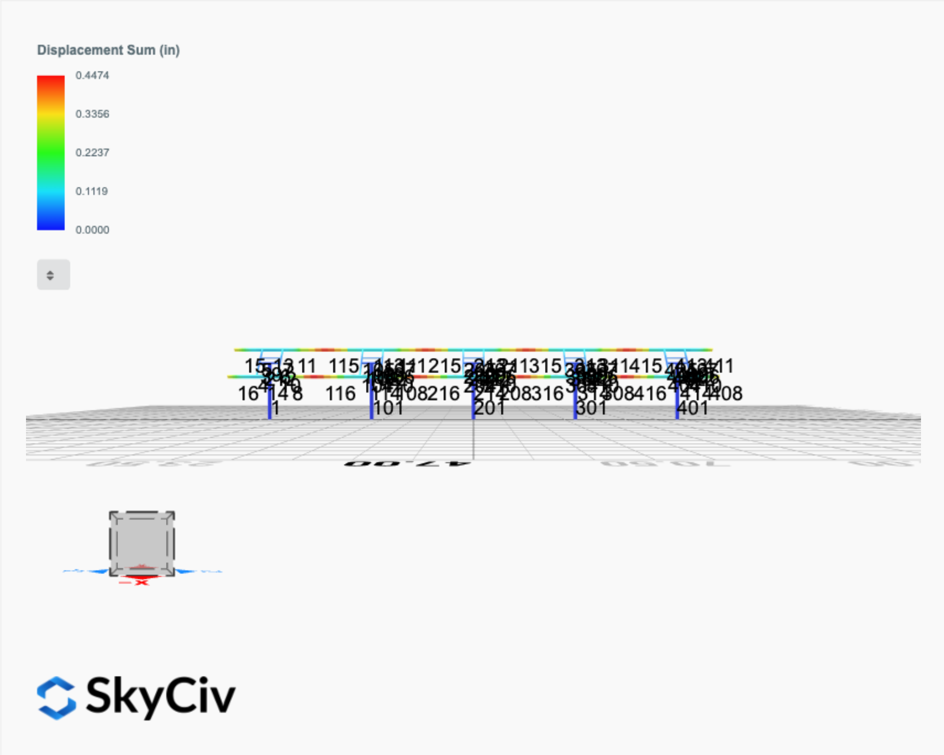


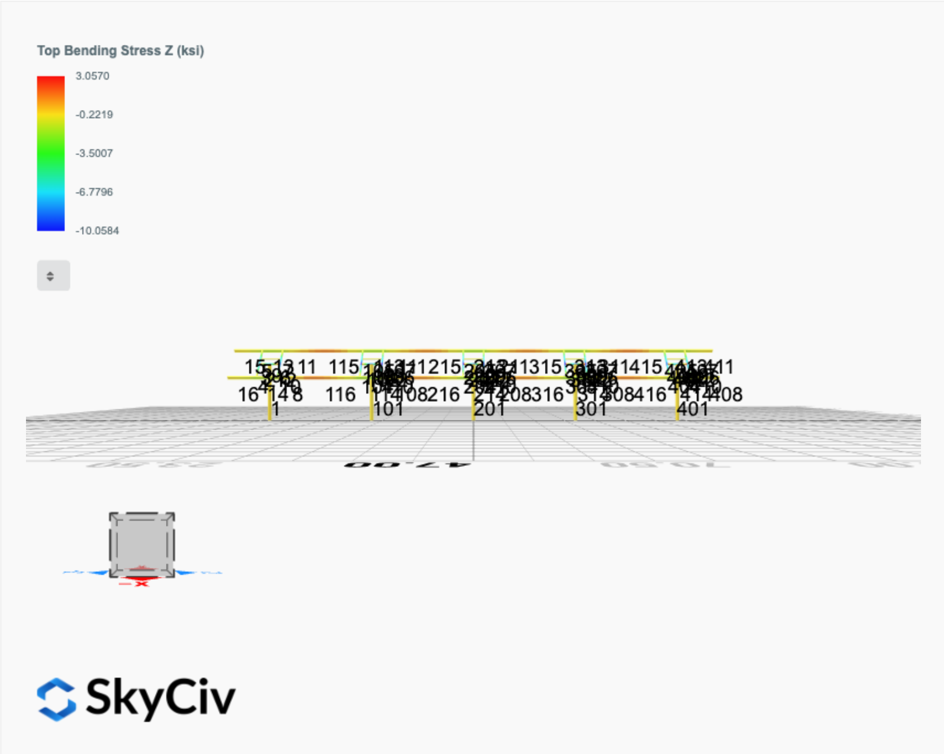


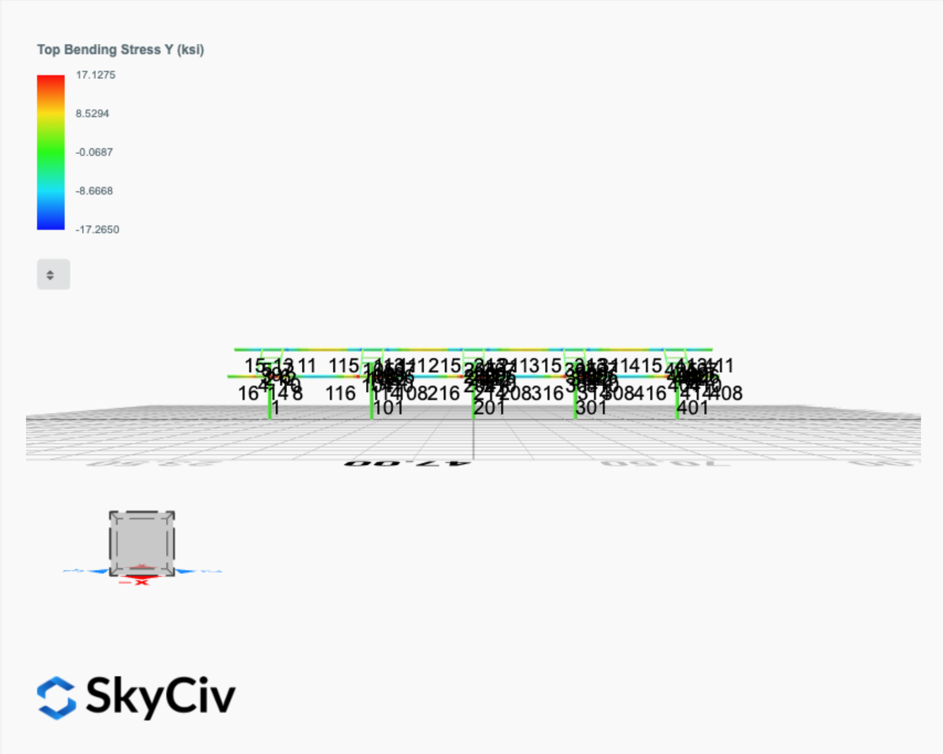


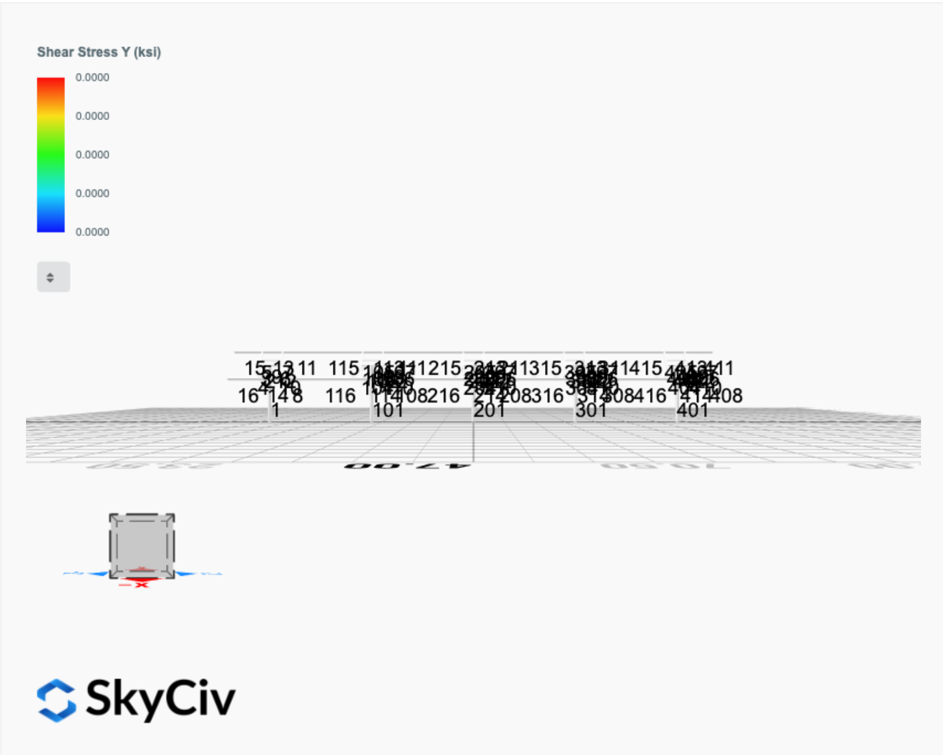


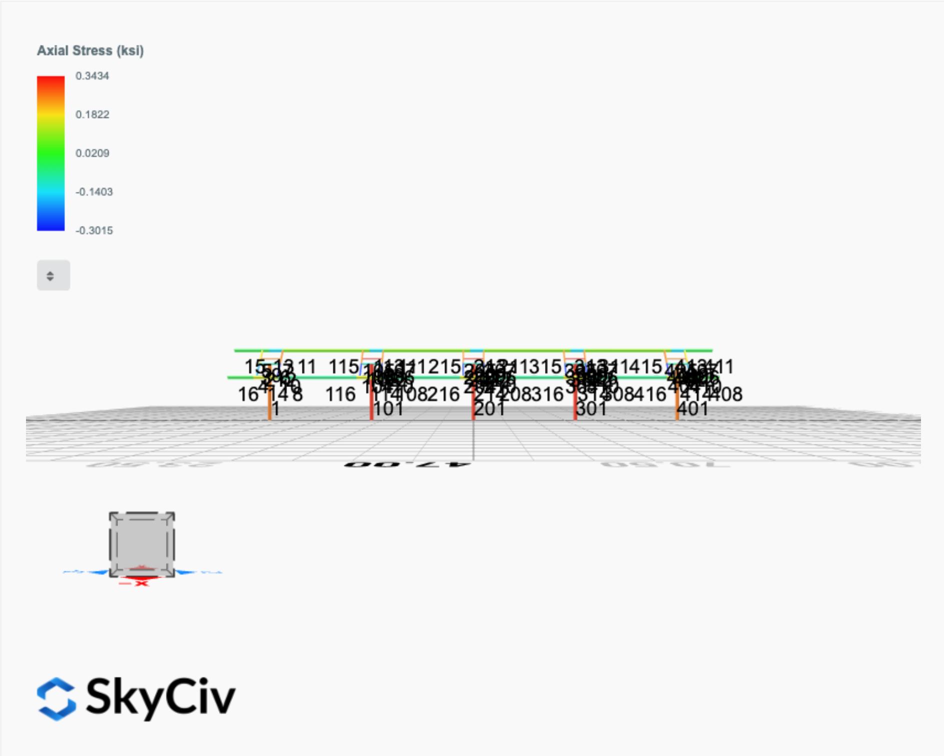
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
17.1275
8.5294
-0.0687
-8.6668
-17.2650


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000


Axial Stress (ksi)
0.3434
0.1822
0.0209
-0.1403
-0.3015
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0074	2.1547	0.0279	0.0845	-0.0063	-0.0555
ULS: 2. D + L	0.0074	2.1547	0.0279	0.0845	-0.0063	-0.0555
ULS: 3. D + (S or Lr or R)	0.0263	5.8808	0.0993	0.3014	-0.0237	-0.2358
ULS: 3. D + (S or Lr or R)	0.0074	2.1547	0.0279	0.0845	-0.0063	-0.0555
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0215	4.9493	0.0814	0.2472	-0.0194	-0.1907
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	2.1547	0.0279	0.0845	-0.0063	-0.0555
ULS: 5b. D + 0.7E	0.0074	2.1547	0.0279	0.0845	-0.0063	-0.0555
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0215	4.9493	0.0814	0.2472	-0.0194	-0.1907
ULS: 8. 0.6D + 0.7E	0.0044	1.2928	0.0168	0.0507	-0.0038	-0.0333
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4334	5.5747	0.1263	0.3464	-0.5094	39.1426
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.4334	5.5747	0.1263	0.3464	-0.5094	39.1426
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4935	-0.3180	-0.0402	-0.0970	0.3417	-26.2514
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2097	-0.0309	-0.0398	-0.0955	0.3441	-30.1139
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5591	7.5143	0.1552	0.4436	-0.3966	29.2078
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5591	7.5143	0.1552	0.4436	-0.3966	29.2078
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8861	3.0947	0.0303	0.1111	0.2417	-19.8376
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6732	3.3101	0.0306	0.1122	0.2435	-22.7345
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5732	4.7197	0.1017	0.2809	-0.3836	29.3431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5732	4.7197	0.1017	0.2809	-0.3836	29.3431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8720	0.3002	-0.0232	-0.0516	0.2547	-19.7024
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6591	0.5155	-0.0229	-0.0505	0.2565	-22.5993
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4364	4.7128	0.1151	0.3126	-0.5068	39.1648
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.4364	4.7128	0.1151	0.3126	-0.5068	39.1648
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4905	-1.1799	-0.0514	-0.1308	0.3443	-26.2292
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2067	-0.8927	-0.0510	-0.1293	0.3466	-30.0917

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	11.3977
Shear X	-5.7347
Shear Z	0.2342
Moment X	0.6724
Moment Y (Twist)	0.8590
Moment Z	65.8141

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	7.5143
Shear X	-3.4364
Shear Z	0.1552
Moment X	0.4436
Moment Y (Twist)	0.5094
Moment Z	39.1648

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	-0.0072	2.3729	-0.0012	-0.0042	0.0055	0.0955
ULS: 2. D + L	-0.0072	2.3729	-0.0012	-0.0042	0.0055	0.0955
ULS: 3. D + (S or Lr or R)	-0.0256	6.6527	-0.0044	-0.0146	0.0194	0.3057
ULS: 3. D + (S or Lr or R)	-0.0072	2.3729	-0.0012	-0.0042	0.0055	0.0955
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0210	5.5828	-0.0036	-0.0120	0.0160	0.2532
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0072	2.3729	-0.0012	-0.0042	0.0055	0.0955
ULS: 5b. D + 0.7E	-0.0072	2.3729	-0.0012	-0.0042	0.0055	0.0955

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0210	5.5828	-0.0036	-0.0120	0.0160	0.2532
ULS: 8. 0.6D + 0.7E	-0.0043	1.4238	-0.0007	-0.0025	0.0033	0.0573
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9262	6.3112	0.0082	0.0168	-0.0712	44.5817
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.9262	6.3112	0.0082	0.0168	-0.0712	44.5817
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.8313	-0.4782	-0.0063	-0.0148	0.0503	-29.6284
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.4874	-0.1368	-0.0103	-0.0253	0.0738	-33.8040
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9603	8.5365	0.0035	0.0037	-0.0416	33.6178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9603	8.5365	0.0035	0.0037	-0.0416	33.6178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1078	3.4444	-0.0074	-0.0200	0.0495	-22.0397
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8499	3.7005	-0.0104	-0.0278	0.0672	-25.1715
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9465	5.3266	0.0058	0.0115	-0.0520	33.4602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9465	5.3266	0.0058	0.0115	-0.0520	33.4602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1217	0.2346	-0.0051	-0.0122	0.0391	-22.1974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8637	0.4906	-0.0080	-0.0200	0.0567	-25.3292
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9233	5.3620	0.0087	0.0184	-0.0734	44.5435
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.9233	5.3620	0.0087	0.0184	-0.0734	44.5435
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8342	-1.4273	-0.0058	-0.0132	0.0481	-29.6666
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.4903	-1.0860	-0.0098	-0.0236	0.0716	-33.8422

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	12.9765
Shear X	-6.5483
Shear Z	-0.0186
Moment X	-0.0465
Moment Y (Twist)	0.1307
Moment Z	75.1490

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	8.5365
Shear X	-3.9262
Shear Z	-0.0104
Moment X	-0.0278
Moment Y (Twist)	0.0738
Moment Z	44.5817

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	-0.0003	2.3647	0.0000	0.0000	0.0000	0.0318
ULS: 2. D + L	-0.0003	2.3647	0.0000	0.0000	0.0000	0.0318
ULS: 3. D + (S or Lr or R)	-0.0012	6.6234	0.0000	-0.0000	0.0000	0.0795
ULS: 3. D + (S or Lr or R)	-0.0003	2.3647	0.0000	0.0000	0.0000	0.0318
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0010	5.5587	0.0000	-0.0000	0.0000	0.0676
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0003	2.3647	0.0000	0.0000	0.0000	0.0318
ULS: 5b. D + 0.7E	-0.0003	2.3647	0.0000	0.0000	0.0000	0.0318
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0010	5.5587	0.0000	-0.0000	0.0000	0.0676
ULS: 8. 0.6D + 0.7E	-0.0002	1.4188	0.0000	0.0000	0.0000	0.0191
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9328	6.3002	0.0000	0.0000	0.0000	44.8419
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.9328	6.3002	0.0000	0.0000	0.0000	44.8419
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.8435	-0.4808	0.0000	0.0000	0.0000	-29.8568
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.5115	-0.1503	0.0000	0.0000	0.0000	-34.2035
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9503	8.5104	0.0000	-0.0000	0.0000	33.6751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9503	8.5104	0.0000	-0.0000	0.0000	33.6751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1319	3.4246	0.0000	-0.0000	0.0000	-22.3489
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8829	3.6725	0.0000	-0.0000	0.0000	-25.6090

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	-2.9497	5.3163	0.0000	0.0000	0.0000	33.6394
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9497	5.3163	0.0000	0.0000	0.0000	33.6394
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1325	0.2306	0.0000	0.0000	0.0000	-22.3846
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8836	0.4784	0.0000	0.0000	0.0000	-25.6447
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9327	5.3543	0.0000	-0.0000	0.0000	44.8292
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.9327	5.3543	0.0000	-0.0000	0.0000	44.8292
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8436	-1.4266	0.0000	0.0000	0.0000	-29.8695
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.5117	-1.0962	0.0000	0.0000	0.0000	-34.2162

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	12.9318
Shear X	-6.5554
Shear Z	0.0000
Moment X	0.0002
Moment Y (Twist)	0.0004
Moment Z	75.5581

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	8.5104
Shear X	-3.9328
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	44.8419

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	-0.0072	2.3729	0.0012	0.0042	-0.0055	0.0955
ULS: 2. D + L	-0.0072	2.3729	0.0012	0.0042	-0.0055	0.0955
ULS: 3. D + (S or Lr or R)	-0.0256	6.6527	0.0044	0.0146	-0.0194	0.3057
ULS: 3. D + (S or Lr or R)	-0.0072	2.3729	0.0012	0.0042	-0.0055	0.0955
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0210	5.5828	0.0036	0.0120	-0.0159	0.2532
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0072	2.3729	0.0012	0.0042	-0.0055	0.0955
ULS: 5b. D + 0.7E	-0.0072	2.3729	0.0012	0.0042	-0.0055	0.0955
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0210	5.5828	0.0036	0.0120	-0.0159	0.2532
ULS: 8. 0.6D + 0.7E	-0.0043	1.4238	0.0007	0.0025	-0.0033	0.0573
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9262	6.3112	-0.0082	-0.0168	0.0712	44.5817
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.9262	6.3112	-0.0082	-0.0168	0.0712	44.5817
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.8313	-0.4782	0.0063	0.0148	-0.0503	-29.6284
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.4874	-0.1368	0.0103	0.0253	-0.0738	-33.8040
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9603	8.5365	-0.0035	-0.0037	0.0416	33.6178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9603	8.5365	-0.0035	-0.0037	0.0416	33.6178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1078	3.4444	0.0074	0.0200	-0.0495	-22.0397
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8499	3.7005	0.0104	0.0278	-0.0671	-25.1715
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9465	5.3266	-0.0058	-0.0115	0.0521	33.4602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9465	5.3266	-0.0058	-0.0115	0.0521	33.4602
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1217	0.2346	0.0051	0.0122	-0.0391	-22.1974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8637	0.4906	0.0080	0.0200	-0.0567	-25.3292
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9233	5.3620	-0.0087	-0.0184	0.0734	44.5435
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.9233	5.3620	-0.0087	-0.0184	0.0734	44.5435
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8342	-1.4273	0.0058	0.0132	-0.0481	-29.6666
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.4903	-1.0860	0.0098	0.0236	-0.0716	-33.8422

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	12.9765
Shear X	-6.5483
Shear Z	0.0186
Moment X	0.0468
Moment Y (Twist)	0.1305
Moment Z	75.1490

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	8.5365
Shear X	-3.9262
Shear Z	0.0104
Moment X	0.0278
Moment Y (Twist)	0.0738
Moment Z	44.5817

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0074	2.1547	-0.0279	-0.0845	0.0063	-0.0555
ULS: 2. D + L	0.0074	2.1547	-0.0279	-0.0845	0.0063	-0.0555
ULS: 3. D + (S or Lr or R)	0.0263	5.8808	-0.0993	-0.3016	0.0238	-0.2357
ULS: 3. D + (S or Lr or R)	0.0074	2.1547	-0.0279	-0.0845	0.0063	-0.0555
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0215	4.9493	-0.0814	-0.2473	0.0194	-0.1906
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	2.1547	-0.0279	-0.0845	0.0063	-0.0555
ULS: 5b. D + 0.7E	0.0074	2.1547	-0.0279	-0.0845	0.0063	-0.0555
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0215	4.9493	-0.0814	-0.2473	0.0194	-0.1906
ULS: 8. 0.6D + 0.7E	0.0044	1.2928	-0.0168	-0.0507	0.0038	-0.0333
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4334	5.5747	-0.1263	-0.3464	0.5094	39.1426
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.4334	5.5747	-0.1263	-0.3464	0.5094	39.1426
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4935	-0.3180	0.0402	0.0970	-0.3417	-26.2514
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2097	-0.0309	0.0398	0.0955	-0.3441	-30.1139
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5591	7.5143	-0.1552	-0.4438	0.3967	29.2079
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5591	7.5143	-0.1552	-0.4438	0.3967	29.2079
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8861	3.0947	-0.0303	-0.1112	-0.2416	-19.8376
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6732	3.3101	-0.0306	-0.1123	-0.2434	-22.7345
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5732	4.7197	-0.1017	-0.2809	0.3836	29.3431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.5732	4.7197	-0.1017	-0.2809	0.3836	29.3431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8720	0.3002	0.0232	0.0516	-0.2547	-19.7024
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6591	0.5155	0.0229	0.0505	-0.2565	-22.5993
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4364	4.7128	-0.1151	-0.3126	0.5068	39.1648
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.4364	4.7128	-0.1151	-0.3126	0.5068	39.1648
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4905	-1.1799	0.0514	0.1308	-0.3443	-26.2292
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2067	-0.8927	0.0510	0.1293	-0.3466	-30.0917

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	11.3977
Shear X	-5.7347
Shear Z	-0.2342
Moment X	-0.6729
Moment Y (Twist)	0.8593
Moment Z	65.8149

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	7.5143
Shear X	-3.4364
Shear Z	-0.1552
Moment X	-0.4438
Moment Y (Twist)	0.5094
Moment Z	39.1648

Project Details

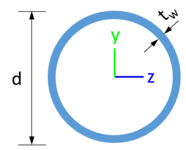
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

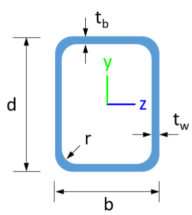
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

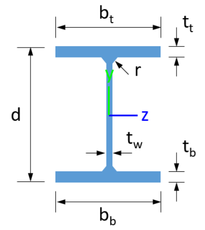
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
10	8in Pipe Sch 80	8.63	0.50					



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



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05

16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	22.90	22.90	10.90	-	300	200	1
2	5	4.20	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.87,1.67,1.67,1.66,1.65	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	19	1.33	1.33	2.05	1.73,1.73,1.73,1.73,1.73,1.73,1.71,1.71,1.71,1.41,1.71,1.71,1.72,1.50,1.72,1.72,1.75,1.78,1.71,1.71,1.71,1.24,1.71,1.71,1.72,1.54	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.39,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.90,1.67,1.67,1.66,1.66	300	200	1
11	19	1.33	1.33	2.05	1.76,1.76,1.76,1.76,1.76,1.76,1.85,1.85,1.94,1.99,1.86,1.86,1.88,1.94,1.81,1.81,1.68,1.51,1.84,1.84,1.94,1.99,1.86,1.86,1.87,1.93	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.10,1.11,1.10,1.11,1.10,1.10,1.10,1.10,1.08,1.11,1.10,1.10,1.09,1.11,1.10,1.10,1.12,1.10,1.10,1.10,1.09,1.11,1.10,1.10,1.09,1.11	300	200	1
14	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.62,1.10,1.10,1.10,1.06,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.45,1.10,1.10,1.10,1.04	300	200	1
15	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	22.90	22.90	10.90	-	300	200	1
102	5	4.20	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.00,1.67,1.67,1.66,1.65	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1

108	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.08,1.63,2.08,2.08,2.08,2.06,2.08,2.08,2.09,2.09,2.08,2.08,2.08,1.37,2.08,2.08,2.08,2.07	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.91,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.17,1.67,1.67,1.66,1.66	300	200	1
111	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.07,1.96,2.06,2.06,2.06,2.06,2.06,2.07,2.07,2.11,2.35,2.07,2.07,1.97,2.06,2.06,2.06,2.06,2.06	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.06,1.07,1.05,1.05,1.06,1.06,1.05,1.05,1.04,1.04,1.05,1.05,1.06,1.07,1.05,1.05,1.06,1.06	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.12,1.05,1.05,1.05,1.05,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.10,1.05,1.05,1.05,1.05	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.12,1.13,1.14,1.14,1.13,1.13,1.14,1.14,1.17,1.20,1.14,1.14,1.12,1.13,1.14,1.14,1.13,1.13	300	200	1
116	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.57,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.15,3.15,1.15,1.15,1.15,1.15	300	200	1
201	10	22.90	22.90	10.90	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.68,1.67,1.67,1.66,1.85,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.05,1.67,1.67,1.66,1.66	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,1.69,2.08,2.08,2.09,2.06,2.08,2.08,2.08,2.09,2.08,2.08,2.09,1.39,2.08,2.08,2.09,2.06	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.68,1.67,1.67,1.66,1.85,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.04,1.67,1.67,1.66,1.66	300	200	1
211	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.07,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.10,2.10,2.08,2.08,2.07,2.08,2.08,2.08,2.08,2.08	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.04,1.04,1.04,1.04,1.04,1.04,1.02,1.04,1.04,1.04,1.03	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.15,1.16	300	200	1
216	19	6.63	6.63	10.20	1.15,1.15,1.15,1.16,1.15,1.15,1.16,1.16,1.16,1.82,1.16,1.16,1.16,1.14,1.16,1.16,1.15,1.16,1.16,1.16,1.16,3.27,1.16,1.16,1.16,1.15	300	200	1
301	10	22.90	22.90	10.90	-	300	200	1

302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.91,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.17,1.67,1.67,1.66,1.66	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
308	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.01,2.07,2.07,2.07,2.06,2.07,2.07,2.08,2.08,2.07,2.07,2.06,1.46,2.07,2.07,2.07,2.07	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.99,1.67,1.67,1.66,1.65	300	200	1
311	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.93,1.93,1.69,1.76,1.90,1.90,1.81,1.83,2.04,2.04,2.11,2.30,1.93,1.93,1.70,1.76,1.89,1.89,1.83,1.84	300	200	1
312	5	4.20	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.06,1.07,1.05,1.05,1.06,1.06,1.05,1.05,1.04,1.04,1.05,1.05,1.06,1.07,1.05,1.05,1.06,1.06	300	200	1
314	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.11,1.05,1.05,1.05,1.05,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.10,1.05,1.05,1.05,1.05	300	200	1
315	19	6.63	6.63	10.20	1.15,1.16,1.15,1.16,1.16,1.15,1.15,1.15,1.14,1.14,1.15,1.15,1.14,1.14,1.15,1.15,1.17,1.19,1.15,1.15,1.14,1.14,1.15,1.15,1.14,1.14	300	200	1
316	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.15,1.94,1.15,1.15,1.15,1.15,1.16,1.16,1.16,1.16,1.15,1.15,1.15,3.23,1.15,1.15,1.15,1.15	300	200	1
401	10	22.90	22.90	10.90	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.40,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.90,1.67,1.67,1.66,1.66	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
406	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
407	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
408	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.87,1.67,1.67,1.66,1.65	300	200	1
411	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	5	4.20	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.10,1.11,1.10,1.11,1.10,1.10,1.10,1.10,1.08,1.11,1.10,1.10,1.09,1.11,1.10,1.10,1.12,1.10,1.10,1.10,1.09,1.11,1.10,1.10,1.09,1.11	300	200	1
414	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.64,1.10,1.10,1.10,1.06,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.45,1.10,1.10,1.10,1.04	300	200	1
415	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.14,1.14,1.13,1.13,1.14,1.14,1.13,1.13,1.12,1.11,1.13,1.13,1.14,1.14,1.13,1.13,1.13,1.14	300	200	1
416	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,2.47,1.12,1.12,1.12,1.10,1.12,1.12,1.12,1.13,1.12,1.12,1.12,2.81,1.12,1.12,1.12,1.11	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	574.32	294.97	123.94	123.94	172.30	172.30
2	198.33	182.14	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	24.75	6.12	40.24	43.62
14	133.20	104.94	23.83	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	574.32	294.97	123.94	123.94	172.30	172.30
102	198.33	182.14	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.83	6.12	40.24	43.62
114	133.20	104.94	23.83	6.12	40.24	43.62
115	133.20	69.16	17.33	6.12	40.24	43.62
116	133.20	69.16	17.80	6.12	40.24	43.62
201	574.32	294.97	123.94	123.94	172.30	172.30
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28

208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	23.60	6.12	40.24	43.62
214	133.20	104.94	23.37	6.12	40.24	43.62
215	133.20	69.16	17.80	6.12	40.24	43.62
216	133.20	69.16	17.64	6.12	40.24	43.62
301	574.32	294.97	123.94	123.94	172.30	172.30
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	126.01	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	126.01	32.87	6.12	40.24	43.62
312	198.33	182.14	21.95	21.95	59.50	59.50
313	133.20	104.94	23.83	6.12	40.24	43.62
314	133.20	104.94	23.83	6.12	40.24	43.62
315	133.20	69.16	17.64	6.12	40.24	43.62
316	133.20	69.16	17.80	6.12	40.24	43.62
401	574.32	294.97	123.94	123.94	172.30	172.30
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	52.83	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	52.83	32.87	6.12	40.24	43.62
412	198.33	182.14	21.95	21.95	59.50	59.50
413	133.20	104.94	24.75	6.12	40.24	43.62
414	133.20	104.94	23.83	6.12	40.24	43.62
415	133.20	69.16	17.18	6.12	40.24	43.62
416	133.20	69.16	17.02	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.039	0.531	0.015	0.033	0.001	0.553	#13	0.477	Not Required	Pass
2	0.004	0.343	0.236	0.082	0.046	0.555	#13	0.114	Not Required	Pass
3	0.011	0.626	0.052	0.062	0.004	0.652	#13	0.045	Not Required	Pass
4	0.010	0.565	0.168	0.057	0.037	0.641	#21	0.080	Not Required	Pass
5	0.010	0.388	0.164	0.062	0.041	0.404	#13	0.074	Not Required	Pass
6	0.014	0.721	0.100	0.073	0.020	0.775	#13	0.045	Not Required	Pass
7	0.014	0.448	0.227	0.072	0.057	0.476	#13	0.074	Not Required	Pass
8	0.002	0.079	0.198	0.043	0.022	0.205	#24	0.095	Not Required	Pass

9	0.015	0.051	0.075	0.002	0.002	0.123	#13	0.204	Not Required	Pass
10	0.014	0.642	0.216	0.064	0.046	0.723	#21	0.080	Not Required	Pass
11	0.003	0.081	0.203	0.049	0.022	0.210	#21	0.095	Not Required	Pass
12	0.003	0.427	0.275	0.100	0.051	0.681	#13	0.053	Not Required	Pass
13	0.007	0.219	0.521	0.063	0.029	0.666	#21	0.286	Not Required	Pass
14	0.008	0.199	0.515	0.056	0.029	0.641	#21	0.190	Not Required	Pass
15	0.000	0.069	0.182	0.030	0.014	0.242	#21	Not Required	Not Required	Pass
16	0.000	0.063	0.182	0.027	0.014	0.239	#21	Not Required	Not Required	Pass
101	0.044	0.606	0.001	0.038	0.000	0.626	#13	0.477	Not Required	Pass
102	0.004	0.441	0.290	0.104	0.054	0.702	#13	0.114	Not Required	Pass
103	0.014	0.761	0.084	0.076	0.012	0.806	#13	0.045	Not Required	Pass
104	0.014	0.699	0.219	0.070	0.047	0.793	#21	0.080	Not Required	Pass
105	0.014	0.472	0.227	0.076	0.057	0.500	#13	0.074	Not Required	Pass
106	0.014	0.772	0.084	0.077	0.013	0.815	#13	0.045	Not Required	Pass
107	0.014	0.480	0.224	0.077	0.056	0.508	#13	0.074	Not Required	Pass
108	0.002	0.056	0.195	0.045	0.022	0.229	#21	0.095	Not Required	Pass
109	0.018	0.053	0.059	0.001	0.000	0.116	#13	0.204	Not Required	Pass
110	0.014	0.700	0.215	0.070	0.046	0.789	#21	0.080	Not Required	Pass
111	0.003	0.067	0.200	0.049	0.022	0.233	#21	0.095	Not Required	Pass
112	0.004	0.442	0.296	0.104	0.056	0.713	#13	0.035	Not Required	Pass
113	0.007	0.231	0.526	0.063	0.029	0.708	#21	0.286	Not Required	Pass
114	0.009	0.228	0.522	0.059	0.029	0.705	#21	0.286	Not Required	Pass
115	0.005	0.298	0.288	0.049	0.022	0.552	#21	0.473	Not Required	Pass
116	0.002	0.270	0.288	0.046	0.022	0.533	#21	0.473	Not Required	Pass
201	0.044	0.610	0.000	0.038	0.000	0.629	#13	0.477	Not Required	Pass
202	0.004	0.440	0.293	0.104	0.055	0.708	#13	0.035	Not Required	Pass
203	0.014	0.771	0.084	0.077	0.012	0.815	#13	0.045	Not Required	Pass
204	0.014	0.694	0.215	0.070	0.046	0.784	#21	0.080	Not Required	Pass
205	0.014	0.479	0.223	0.077	0.056	0.506	#13	0.074	Not Required	Pass
206	0.014	0.771	0.084	0.077	0.012	0.815	#13	0.045	Not Required	Pass
207	0.014	0.479	0.223	0.077	0.056	0.506	#13	0.074	Not Required	Pass
208	0.002	0.056	0.195	0.045	0.022	0.230	#21	0.095	Not Required	Pass
209	0.017	0.051	0.059	0.001	0.000	0.114	#13	0.204	Not Required	Pass
210	0.014	0.694	0.215	0.070	0.046	0.784	#21	0.080	Not Required	Pass
211	0.003	0.063	0.199	0.050	0.022	0.237	#21	0.095	Not Required	Pass
212	0.004	0.440	0.293	0.104	0.055	0.708	#13	0.035	Not Required	Pass
213	0.007	0.243	0.517	0.064	0.029	0.714	#21	0.286	Not Required	Pass
214	0.009	0.228	0.511	0.057	0.029	0.696	#21	0.286	Not Required	Pass
215	0.005	0.268	0.288	0.050	0.022	0.522	#21	0.473	Not Required	Pass
216	0.002	0.240	0.288	0.045	0.022	0.505	#21	0.473	Not Required	Pass
301	0.044	0.606	0.001	0.038	0.000	0.626	#13	0.477	Not Required	Pass
302	0.004	0.442	0.296	0.104	0.056	0.713	#13	0.035	Not Required	Pass
303	0.014	0.772	0.084	0.077	0.013	0.815	#13	0.045	Not Required	Pass
304	0.014	0.700	0.215	0.070	0.046	0.789	#21	0.080	Not Required	Pass
305	0.014	0.480	0.224	0.077	0.056	0.508	#13	0.074	Not Required	Pass
306	0.014	0.761	0.084	0.076	0.012	0.806	#13	0.045	Not Required	Pass
307	0.014	0.472	0.227	0.076	0.057	0.500	#13	0.074	Not Required	Pass
308	0.002	0.065	0.203	0.046	0.022	0.233	#21	0.095	Not Required	Pass
309	0.018	0.053	0.059	0.001	0.000	0.116	#13	0.204	Not Required	Pass
310	0.014	0.699	0.219	0.070	0.047	0.793	#21	0.080	Not Required	Pass
311	0.003	0.079	0.207	0.049	0.022	0.234	#21	0.095	Not Required	Pass
312	0.004	0.441	0.290	0.104	0.054	0.702	#13	0.114	Not Required	Pass
313	0.007	0.231	0.526	0.063	0.029	0.708	#21	0.286	Not Required	Pass
314	0.009	0.228	0.522	0.059	0.029	0.705	#21	0.286	Not Required	Pass

315	0.005	0.270	0.288	0.049	0.022	0.524	#21	0.473	Not Required	Pass
316	0.002	0.238	0.288	0.045	0.022	0.505	#21	0.473	Not Required	Pass
401	0.039	0.531	0.015	0.033	0.001	0.553	#13	0.477	Not Required	Pass
402	0.003	0.427	0.275	0.100	0.051	0.681	#13	0.053	Not Required	Pass
403	0.014	0.721	0.100	0.073	0.020	0.775	#13	0.045	Not Required	Pass
404	0.014	0.642	0.216	0.064	0.046	0.723	#21	0.080	Not Required	Pass
405	0.014	0.448	0.227	0.072	0.057	0.476	#13	0.074	Not Required	Pass
406	0.011	0.626	0.052	0.062	0.004	0.652	#13	0.045	Not Required	Pass
407	0.010	0.388	0.164	0.062	0.041	0.404	#13	0.074	Not Required	Pass
408	0.000	0.063	0.182	0.027	0.014	0.239	#21	Not Required	Not Required	Pass
409	0.015	0.051	0.075	0.002	0.002	0.123	#13	0.204	Not Required	Pass
410	0.010	0.565	0.168	0.057	0.037	0.641	#21	0.080	Not Required	Pass
411	0.000	0.069	0.182	0.030	0.014	0.242	#21	Not Required	Not Required	Pass
412	0.004	0.343	0.236	0.082	0.046	0.555	#13	0.114	Not Required	Pass
413	0.007	0.219	0.521	0.063	0.029	0.666	#21	0.190	Not Required	Pass
414	0.008	0.199	0.515	0.056	0.029	0.641	#21	0.286	Not Required	Pass
415	0.005	0.306	0.288	0.049	0.022	0.553	#21	0.473	Not Required	Pass
416	0.002	0.275	0.288	0.043	0.022	0.538	#21	0.473	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

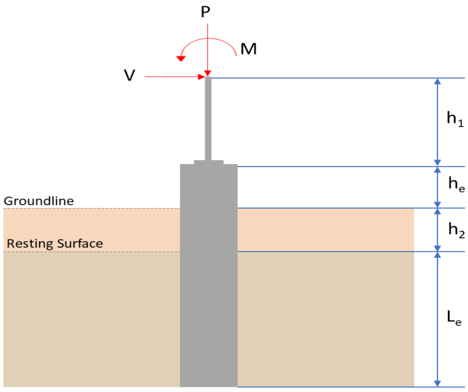
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 15\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.514	11.398
V_x (kip)	-3.436	-5.735
V_z (kip)	0.155	0.234
M_x (kipft)	0.444	0.672
M_z (kipft)	39.165	65.814

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,

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

$$H_o = \frac{(-3.436\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.1453\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.165\ \text{kipft}) + ((-3.436\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 13.055\ \text{kipft/ft}$$

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:
$L_{e,x} = 8.8264\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.155\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.051667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.444\ \text{kipft}) + ((0.155\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.148\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.2537\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.8264\ \text{ft}), (3.2537\ \text{ft})]$$

$$L_{e,req} = 8.826\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 15\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.826\ \text{ft})}{(15\ \text{ft})}$$

$$Ratio = 0.5884$$

Status: **PASS**
Ratio: **0.590**

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

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

$$q = \frac{(7.514\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.063\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.063\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.53151$$

Status: **PASS**
Ratio: **0.530**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.1453\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 13.055\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.055\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (13.055\ \mathrm{kipft/ft})) + (4 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.584\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (13.055\ \mathrm{kipft/ft})) + (3 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (13.055\ \mathrm{kipft/ft})) + (2 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.00050384\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (13.055\ \mathrm{kipft/ft})) + ((-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.37407\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.584\ \mathrm{ft})}{2}$$

$$p_a = 0.79381\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00050384\ \mathrm{kip/ft^2}\right)}{\left(0.79381\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0006347$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.37407\ \mathrm{kip/ft^2}\right)}{\left(2.25\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.16625$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$H_o = 0.051667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.148\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.148\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (0.148\ \mathrm{kipft/ft})) + (4 \times (0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.972\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.148\ \mathrm{kipft/ft})) + (3 \times (0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^{\ 2}}{(15\ \mathrm{ft})^2 \times [(3 \times (0.148\ \mathrm{kipft/ft})) + (2 \times (0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.022341\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.148\ \mathrm{kipft/ft})) + ((0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.044863\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.972\ \mathrm{ft})}{2}$$

$$p_a = 0.82287\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.022341\ \mathrm{kip/ft^2}\right)}{\left(0.82287\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.02715$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

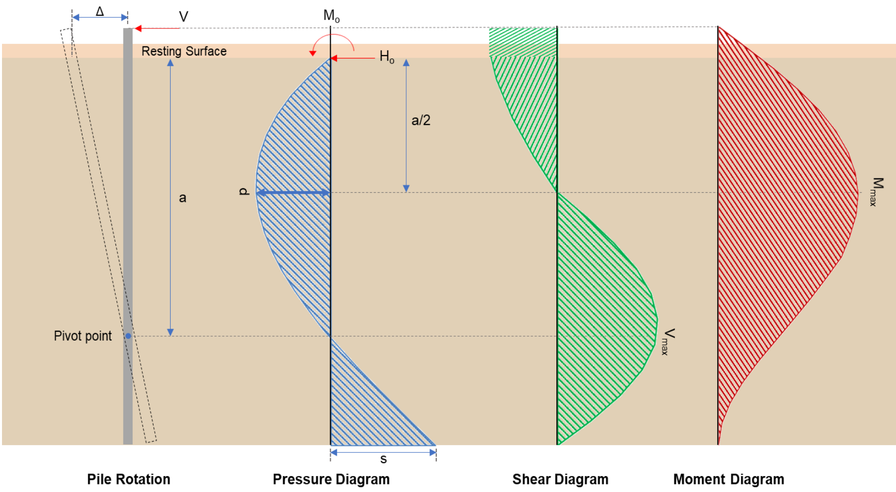
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.044863\ \mathrm{kip/ft^2})}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.01994$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.735\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.9117\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(65.814\ \mathrm{kipft}) + ((-5.735\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 21.938\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(21.938\ \mathrm{kipft/ft})}{(-1.9117\ \mathrm{kip/ft})}$$

$$E = 11.476\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (21.938\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.9117\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (21.938\ \mathrm{kipft/ft})) + (4 \times (-1.9117\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.582\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.9117\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.476\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.582\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.476\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.582\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.562 \text{ kip}$$

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

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

$$M_{max} = ((-1.9117 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(11.476 \text{ ft})}{(15 \text{ ft})} + \frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.476 \text{ ft})}{(15 \text{ ft})} + 3\right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.476 \text{ ft})}{(15 \text{ ft})} + 2\right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 78.998 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.234 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.078 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.672 \text{ kipft}) + ((0.234 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.224 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.224 \text{ kipft/ft})}{(0.078 \text{ kip/ft})}$$

$$E = 2.8718 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.224 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (0.078 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.224 \text{ kipft/ft})) + (4 \times (0.078 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 10.971 \text{ ft}$$

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

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

$$V_{max} = ((0.078 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8718 \text{ ft})}{(15 \text{ ft})} + 3\right) \times \left(\frac{(10.971 \text{ ft})}{(15 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8718 \text{ ft})}{(15 \text{ ft})} + 2\right) \times \left(\frac{(10.971 \text{ ft})}{(15 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.2374 \text{ kip}$$

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

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

$$M_{max} = ((0.078 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(2.8718 \text{ ft})}{(15 \text{ ft})} + \frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.8718 \text{ ft})}{(15 \text{ ft})} + 3\right) \times \left(\frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8718 \text{ ft})}{(15 \text{ ft})} + 2\right) \times \left(\frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.4708 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.398 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.017 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.017 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(11.398\text{ kip})}{(1253.9\text{ kip})}$$ $$Ratio = 0.00909$$	Status: **PASS** Ratio: **0.010**

22.5.2.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\text{ in})$$ $$d = 28.8\text{ in}$$	
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 $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 11.398\text{ kip} \rightarrow 11398\text{ lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(11398\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,a} = 76.373\text{ kip}$$ 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\text{ kip}), (76.373\text{ kip}), (204.04\text{ kip})\right]$$	

$$V_c = 76.373\ \mathrm{kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.373\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 74.453\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 11.562\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.562\ \mathrm{kip})}{(74.453\ \mathrm{kip})}$$

$$Ratio = 0.1553$$

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

Considering z-direction:

$V_{max} = 0.2374\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.2374\ \mathrm{kip})}{(74.453\ \mathrm{kip})}$$

$$Ratio = 0.0031886$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

$\lambda = 1$ - 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:

$M_{max} = 78.998 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(78.998 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 1.2736$$

Status: **FAIL**
Ratio: **1.270**

Considering z-direction:

$M_{max} = 1.4708 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.4708 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.023712$$

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

REFERENCES	CALCULATIONS	RESULTS

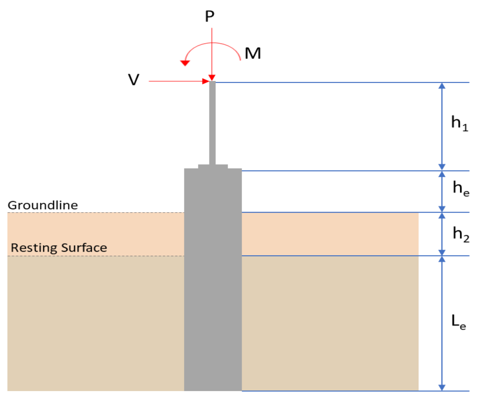
SkyCiv Foundation Design

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
$L = 15 \text{ ft}$ - 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)	8.536	12.976
V_x (kip)	-3.926	-6.548
V_z (kip)	-0.010	-0.019
M_x (kipft)	-0.028	-0.046
M_z (kipft)	44.582	75.149

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,

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

$$H_o = \frac{(-3.926 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.3087 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.582 \text{ kipft}) + ((-3.926 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.861 \text{ kipft/ft}$$

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:
$L_{e,x} = 9.0766 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.01 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0033333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.028 \text{ kipft}) + ((-0.01 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.0093333 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.95556 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(9.0766 \text{ ft}), (0.95556 \text{ ft})]$$

$$L_{e,req} = 9.077 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 15 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.077 \text{ ft})}{(15 \text{ ft})}$$

$$Ratio = 0.60513$$

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

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

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

$$q = \frac{(8.536 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.2076\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.2076\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.6038$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.3087\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 14.861\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.861\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (14.861\ \mathrm{kipft/ft})) + (4 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.585\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (14.861\ \mathrm{kipft/ft})) + (3 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^{\ 2}}{(15\ \mathrm{ft})^2 \times [(3 \times (14.861\ \mathrm{kipft/ft})) + (2 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.00030048\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (14.861\ \mathrm{kipft/ft})) + ((-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.42271\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.585\ \mathrm{ft})}{2}$$

$$p_a = 0.7939\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00030048\ \mathrm{kip/ft^2}\right)}{\left(0.7939\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00037848$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.42271\ \mathrm{kip/ft^2}\right)}{\left(2.25\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.18787$$

Status: **PASS**
Ratio: **0.190**

Considering z-direction:

$H_o = -0.0033333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0093333\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0093333\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (0.0093333\ \mathrm{kipft/ft})) + (4 \times (-0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.977\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.0093333\ \mathrm{kipft/ft})) + (3 \times (-0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^{\ 2}}{(15\ \mathrm{ft})^2 \times [(3 \times (0.0093333\ \mathrm{kipft/ft})) + (2 \times (-0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = -0.00092304\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.0093333\ \mathrm{kipft/ft})) + ((-0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = -0.0013125\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.977\ \mathrm{ft})}{2}$$

$$p_a = 0.82324\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00092304\ \mathrm{kip/ft^2}\right)}{\left(0.82324\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0011212$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

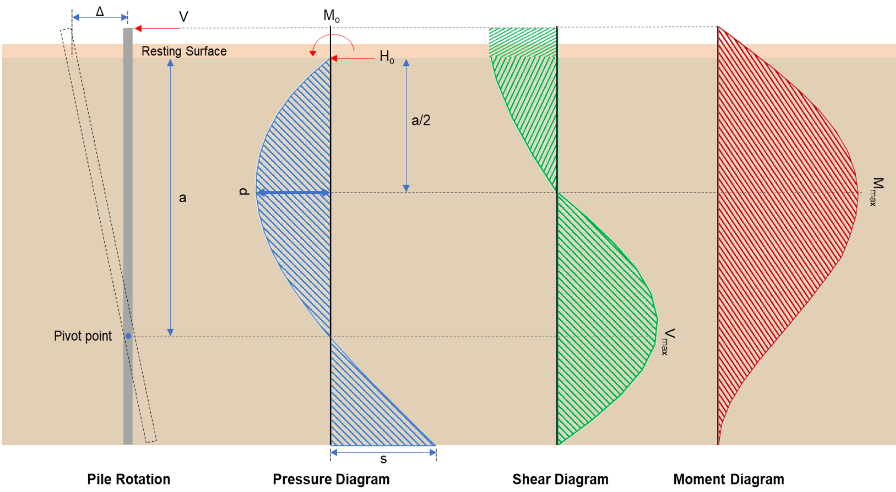
$$Ratio = \frac{s}{\;}$$

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

$$Ratio = \frac{(-0.0013125\ \mathrm{kip/ft^2})}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.00058334$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.548\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -2.1827\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(75.149\ \mathrm{kipft}) + ((-6.548\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 25.05\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(25.05\ \mathrm{kipft/ft})}{(-2.1827\ \mathrm{kip/ft})}$$

$$E = 11.477\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (25.05\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-2.1827\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (25.05\ \mathrm{kipft/ft})) + (4 \times (-2.1827\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.582\ \mathrm{ft}$$

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

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

$$V_{max} = ((-2.1827\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.477\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.582\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.477\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.582\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.202 \text{ kip}$$

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

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

$$M_{max} = ((-2.1827 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(11.477 \text{ ft})}{(15 \text{ ft})} + \frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 90.201 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.019 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0063333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.046 \text{ kipft}) + ((-0.019 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.015333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015333 \text{ kipft/ft})}{(-0.0063333 \text{ kip/ft})}$$

$$E = 2.4211 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015333 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (-0.0063333 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.015333 \text{ kipft/ft})) + (4 \times (-0.0063333 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 11.006 \text{ ft}$$

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

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

$$V_{max} = ((-0.0063333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4211 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(11.006 \text{ ft})}{(15 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.4211 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(11.006 \text{ ft})}{(15 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.018293 \text{ kip}$$

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

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

$$M_{max} = ((-0.0063333 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(2.4211 \text{ ft})}{(15 \text{ ft})} + \frac{(11.006 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.4211 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(11.006 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.4211 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(11.006 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11208 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.976 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -36.968 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.968 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

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

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

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

$$Ratio = 0.99533$$

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)		

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

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

$$Ratio = \frac{(12.976\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.010348$$

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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 12.976\ \text{kip} \rightarrow 12976\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(12976\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.641\ \text{kip}$$

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

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.641\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.641 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.641 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.627 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.202 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.202 \text{ kip})}{(74.627 \text{ kip})}$$

$$Ratio = 0.17691$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$V_{max} = 0.018293 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.018293 \text{ kip})}{(74.627 \text{ kip})}$$

$$Ratio = 0.00024513$$

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:** $M_{max} = 90.201 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(90.201 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 1.4542$$	Status: **FAIL** Ratio: **1.450**
	Considering z-direction: $M_{max} = 0.11208 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.11208 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.001807$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

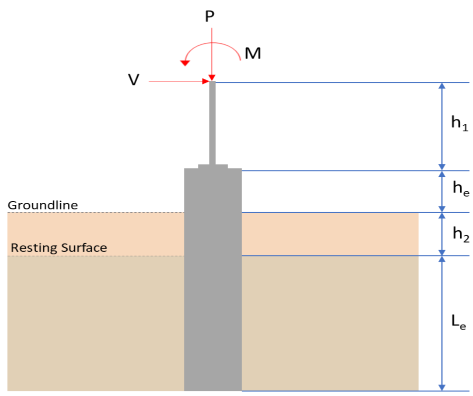
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 15\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.510	12.932
V_x (kip)	-3.933	-6.555
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	44.842	75.558

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,

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

$$H_o = \frac{(-3.933\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.311\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.842 \text{ kipft}) + ((-3.933 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.947 \text{ kipft/ft}$$

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:
$L_{e,x} = 9.1005 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

$L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(9.1005 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 9.101 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 15 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.101 \text{ ft})}{(15 \text{ ft})}$$

$$Ratio = 0.60673$$

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

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

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

$$q = \frac{(8.51 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.2039 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.2039 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.60196$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.311\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 14.947\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.947\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.311\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (14.947\ \mathrm{kipft/ft})) + (4 \times (-1.311\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.584\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (14.947\ \mathrm{kipft/ft})) + (3 \times (-1.311\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (14.947\ \mathrm{kipft/ft})) + (2 \times (-1.311\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.00059932\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (14.947\ \mathrm{kipft/ft})) + ((-1.311\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.42851\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.584\ \mathrm{ft})}{2}$$

$$p_a = 0.79381\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00059932\ \mathrm{kip/ft^2}\right)}{(0.79381\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.000755$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

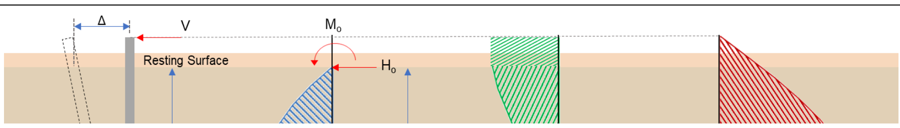
$Ratio$ - Lateral soil capacity

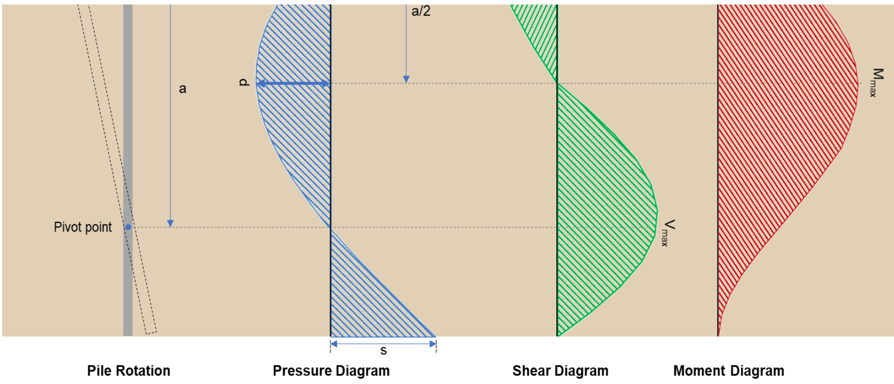
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.42851\ \mathrm{kip/ft^2}\right)}{(2.25\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.19045$$

Status: **PASS**
Ratio: **0.190**





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.555\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -2.185\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(75.558\ \mathrm{kipft}) + ((-6.555\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 25.186\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(25.186\ \mathrm{kipft/ft})}{(-2.185\ \mathrm{kip/ft})}$$

$$E = 11.527\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (25.186\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-2.185\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (25.186\ \mathrm{kipft/ft})) + (4 \times (-2.185\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.581\ \mathrm{ft}$$

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

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

$$V_{max} = ((-2.185\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.527\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.581\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.527\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.581\ \mathrm{ft})}{(15\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.255\ \mathrm{kip}$$

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

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

$$M_{max} = ((-2.185\ \mathrm{kip/ft}) \times (36\ \mathrm{in}) \times (15\ \mathrm{ft})) \times \left[\left(\frac{(11.527\ \mathrm{ft})}{(15\ \mathrm{ft})} + \frac{(10.581\ \mathrm{ft})}{2 \times (15\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.527\ \mathrm{ft})}{(15\ \mathrm{ft})} + 3\right) \times \left(\frac{(10.581\ \mathrm{ft})}{2 \times (15\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.527\ \mathrm{ft})}{(15\ \mathrm{ft})} + 2\right) \times \left(\frac{(10.581\ \mathrm{ft})}{2 \times (15\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 90.586 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5$ ksi - Concrete strength,
$f_{yk} = 60$ 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.932 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -36.969 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.969 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

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

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.932\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.010313$$

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 $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 12.932\ \mathrm{kip} \rightarrow 12932\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(12932\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 76.633\ \mathrm{kip}$$

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

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (76.633\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 76.633 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.633 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.622 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.255 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.255 \text{ kip})}{(74.622 \text{ kip})}$$

$$Ratio = 0.17762$$

Status: **PASS**
Ratio: **0.180**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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:

$M_{max} = 90.586\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(90.586\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 1.4604$$

Status: **FAIL**
Ratio: **1.460**

REFERENCES	CALCULATIONS	RESULTS

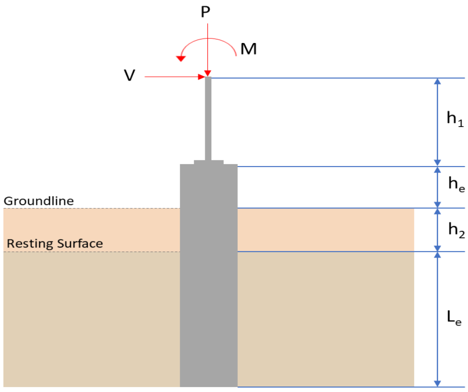
SkyCiv Foundation Design

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

$L = 15\ \mathrm{ft}$ - Total pile length

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

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

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.536	12.976
V_x (kip)	-3.926	-6.548
V_z (kip)	0.010	0.019
M_x (kipft)	0.028	0.047
M_z (kipft)	44.582	75.149

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,

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

$$H_o = \frac{(-3.926\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.3087\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.582 \text{ kipft}) + ((-3.926 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.861 \text{ kipft/ft}$$

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:
$L_{e,x} = 9.0766 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.01 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0033333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.028 \text{ kipft}) + ((0.01 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.0093333 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.1534 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(9.0766 \text{ ft}), (1.1534 \text{ ft})]$$

$$L_{e,req} = 9.077 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 15 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.077 \text{ ft})}{(15 \text{ ft})}$$

$$Ratio = 0.60513$$

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

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

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

$$q = \frac{(8.536 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.2076\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.2076\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.6038$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.3087\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 14.861\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.861\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (14.861\ \mathrm{kipft/ft})) + (4 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.585\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (14.861\ \mathrm{kipft/ft})) + (3 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (14.861\ \mathrm{kipft/ft})) + (2 \times (-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.00030048\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (14.861\ \mathrm{kipft/ft})) + ((-1.3087\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.42271\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.585\ \mathrm{ft})}{2}$$

$$p_a = 0.7939\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00030048\ \mathrm{kip/ft^2}\right)}{\left(0.7939\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00037848$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.42271\ \mathrm{kip/ft^2}\right)}{\left(2.25\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.18787$$

Status: **PASS**
Ratio: **0.190**

Considering z-direction:

$H_o = 0.0033333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0093333\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0093333\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (0.0093333\ \mathrm{kipft/ft})) + (4 \times (0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.977\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.0093333\ \mathrm{kipft/ft})) + (3 \times (0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (0.0093333\ \mathrm{kipft/ft})) + (2 \times (0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.0014354\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.0093333\ \mathrm{kipft/ft})) + ((0.0033333\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.0028764\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.977\ \mathrm{ft})}{2}$$

$$p_a = 0.82324\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0014354\ \mathrm{kip/ft^2}\right)}{\left(0.82324\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0017436$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

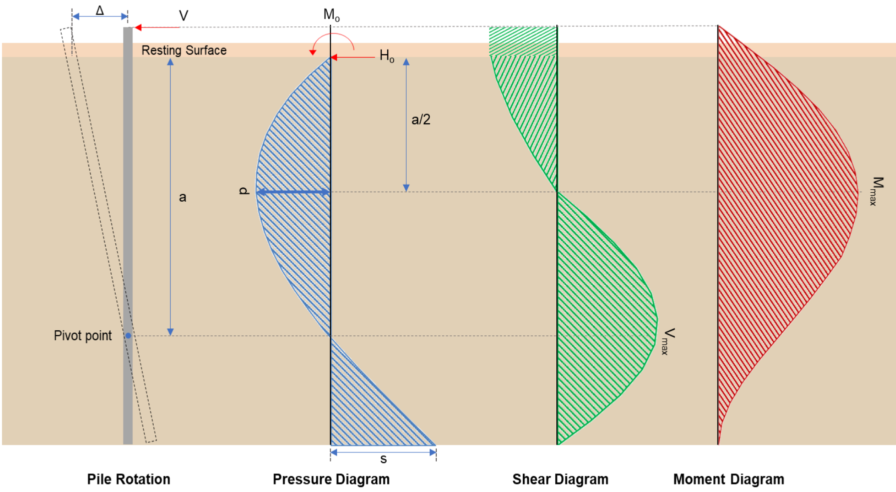
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(0.0028764 \text{ kip/ft}^2\right)}{\left(2.25 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0012784$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.548 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -2.1827 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(75.149 \text{ kipft}) + ((-6.548 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 25.05 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(25.05 \text{ kipft/ft})}{(-2.1827 \text{ kip/ft})}$$

$$E = 11.477 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (25.05 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (-2.1827 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (25.05 \text{ kipft/ft})) + (4 \times (-2.1827 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 10.582 \text{ ft}$$

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

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

$$V_{max} = ((-2.1827 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 3\right) \times \left(\frac{(10.582 \text{ ft})}{(15 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 2\right) \times \left(\frac{(10.582 \text{ ft})}{(15 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 13.202 \text{ kip}$$

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

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

$$M_{max} = ((-2.1827 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(11.477 \text{ ft})}{(15 \text{ ft})} + \frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.477 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 90.201 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.019 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0063333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.047 \text{ kipft}) + ((0.019 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.015667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015667 \text{ kipft/ft})}{(0.0063333 \text{ kip/ft})}$$

$$E = 2.4737 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015667 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (0.0063333 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.015667 \text{ kipft/ft})) + (4 \times (0.0063333 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 11.002 \text{ ft}$$

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

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

$$V_{max} = ((0.0063333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4737 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(11.002 \text{ ft})}{(15 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.4737 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(11.002 \text{ ft})}{(15 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.018408 \text{ kip}$$

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

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

$$M_{max} = ((0.0063333 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(2.4737 \text{ ft})}{(15 \text{ ft})} + \frac{(11.002 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.4737 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(11.002 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.4737 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(11.002 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11294 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.976 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -36.968 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-36.968 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

	Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.976\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.010348$$

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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 12.976\ \text{kip} \rightarrow 12976\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(12976\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.641\ \text{kip}$$

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

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.641\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.641\ \mathrm{kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.641\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 74.627\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 13.202\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.202\ \mathrm{kip})}{(74.627\ \mathrm{kip})}$$

$$Ratio = 0.17691$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$V_{max} = 0.018408\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.018408\ \mathrm{kip})}{(74.627\ \mathrm{kip})}$$

$$Ratio = 0.00024666$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

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:

$M_{max} = 90.201 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(90.201 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 1.4542$$

Status: **FAIL**
Ratio: **1.450**

Considering z-direction:

$M_{max} = 0.11294 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.11294 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0018208$$

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

REFERENCES	CALCULATIONS	RESULTS

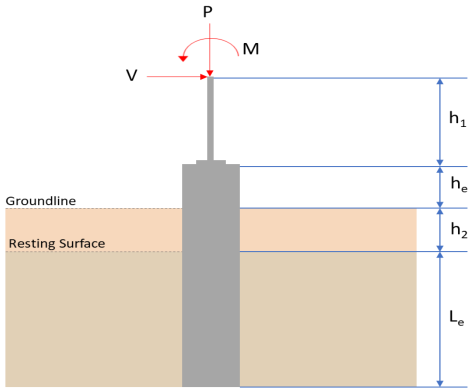
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 15 \text{ ft}$ - 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)	7.514	11.398
V_x (kip)	-3.436	-5.735
V_z (kip)	-0.155	-0.234
M_x (kipft)	-0.444	-0.673
M_z (kipft)	39.165	65.815

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,

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

$$H_o = \frac{(-3.436 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1453 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.165 \text{ kipft}) + ((-3.436 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 13.055 \text{ kipft/ft}$$

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:
$L_{e,x} = 8.8264 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.155 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.051667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.444 \text{ kipft}) + ((-0.155 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.148 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.0499 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.8264 \text{ ft}), (2.0499 \text{ ft})]$$

$$L_{e,req} = 8.826 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (15 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 15 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.826 \text{ ft})}{(15 \text{ ft})}$$

$$Ratio = 0.5884$$

Status: **PASS**
Ratio: **0.590**

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

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

$$q = \frac{(7.514 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.063\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.063\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.53151$$

Status: **PASS**
Ratio: **0.530**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(15\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.1453\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 13.055\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.055\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (13.055\ \mathrm{kipft/ft})) + (4 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.584\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (13.055\ \mathrm{kipft/ft})) + (3 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^{\ 2}}{(15\ \mathrm{ft})^2 \times [(3 \times (13.055\ \mathrm{kipft/ft})) + (2 \times (-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = 0.00050384\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (13.055\ \mathrm{kipft/ft})) + ((-1.1453\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = 0.37407\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.584\ \mathrm{ft})}{2}$$

$$p_a = 0.79381\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00050384\ \mathrm{kip/ft^2}\right)}{\left(0.79381\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0006347$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.37407\ \mathrm{kip/ft^2}\right)}{\left(2.25\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.16625$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$H_o = -0.051667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.148\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.148\ \mathrm{kipft/ft}) \times (15\ \mathrm{ft})) + \left(3 \times (-0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft})^2\right)}{(6 \times (0.148\ \mathrm{kipft/ft})) + (4 \times (-0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))}$$

$$a = 10.972\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.148\ \mathrm{kipft/ft})) + (3 \times (-0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]^2}{(15\ \mathrm{ft})^2 \times [(3 \times (0.148\ \mathrm{kipft/ft})) + (2 \times (-0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}$$

$$p = -0.014217\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.148\ \mathrm{kipft/ft})) + ((-0.051667\ \mathrm{kip/ft}) \times (15\ \mathrm{ft}))]}{(15\ \mathrm{ft})^2}$$

$$s = -0.020065\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(10.972\ \mathrm{ft})}{2}$$

$$p_a = 0.82287\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.014217\ \mathrm{kip/ft^2}\right)}{\left(0.82287\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.017277$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (15\ \mathrm{ft})$$

$$p_s = 2.25\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

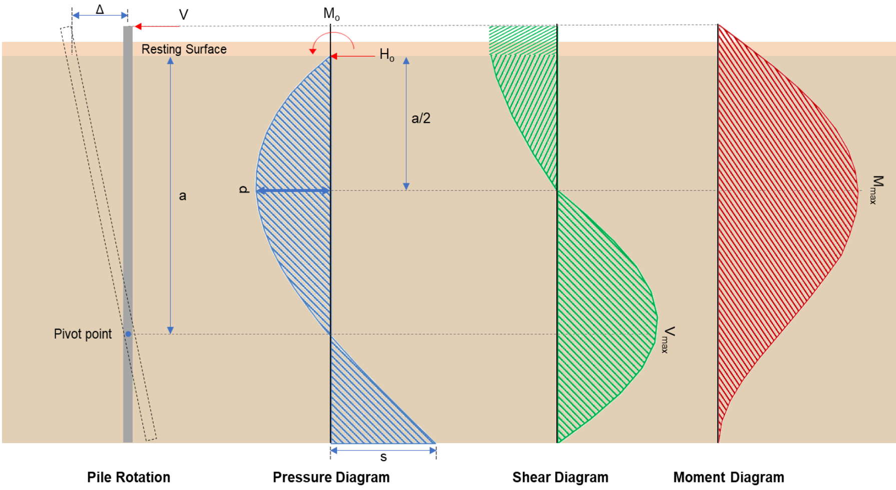
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.020065\ \mathrm{kip/ft^2}\right)}{\left(2.25\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0089177$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{\left(-5.735\ \mathrm{kip}\right)}{\left(36\ \mathrm{in}\right)}$$

$$H_o = -1.9117\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{\left(65.815\ \mathrm{kipft}\right) + \left(\left(-5.735\ \mathrm{kip}\right) \times \left(0\ \mathrm{ft}\right)\right)}{\left(36\ \mathrm{in}\right)}$$

$$M_o = 21.938\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{\left(21.938\ \mathrm{kipft/ft}\right)}{\left(-1.9117\ \mathrm{kip/ft}\right)}$$

$$E = 11.476\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(21.938\ \mathrm{kipft/ft}\right) \times \left(15\ \mathrm{ft}\right)\right) + \left(3 \times \left(-1.9117\ \mathrm{kip/ft}\right) \times \left(15\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(21.938\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-1.9117\ \mathrm{kip/ft}\right) \times \left(15\ \mathrm{ft}\right)\right)}$$

$$a = 10.582\ \mathrm{ft}$$

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

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

$$V_{max} = \left(\left(-1.9117\ \mathrm{kip/ft}\right) \times \left(36\ \mathrm{in}\right)\right) \times \left[1 - \left[3 \times \left(\frac{4 \times \left(11.476\ \mathrm{ft}\right)}{\left(15\ \mathrm{ft}\right)} + 3\right) \times \left(\frac{\left(10.582\ \mathrm{ft}\right)}{\left(15\ \mathrm{ft}\right)}\right)^2\right] + \left[4 \times \left(\frac{3 \times \left(11.476\ \mathrm{ft}\right)}{\left(15\ \mathrm{ft}\right)} + 2\right) \times \left(\frac{\left(10.582\ \mathrm{ft}\right)}{\left(15\ \mathrm{ft}\right)}\right)^3\right]\right]$$

$$V_{max} = 11.562 \text{ kip}$$

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

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

$$M_{max} = ((-1.9117 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(11.476 \text{ ft})}{(15 \text{ ft})} + \frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.476 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.476 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.582 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 79 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.234 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.078 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.673 \text{ kipft}) + ((-0.234 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.22433 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.22433 \text{ kipft/ft})}{(-0.078 \text{ kip/ft})}$$

$$E = 2.8761 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.22433 \text{ kipft/ft}) \times (15 \text{ ft})) + \left(3 \times (-0.078 \text{ kip/ft}) \times (15 \text{ ft})^2\right)}{(6 \times (0.22433 \text{ kipft/ft})) + (4 \times (-0.078 \text{ kip/ft}) \times (15 \text{ ft}))}$$

$$a = 10.971 \text{ ft}$$

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

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

$$V_{max} = ((-0.078 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8761 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.971 \text{ ft})}{(15 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.8761 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.971 \text{ ft})}{(15 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.23752 \text{ kip}$$

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

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

$$M_{max} = ((-0.078 \text{ kip/ft}) \times (36 \text{ in}) \times (15 \text{ ft})) \times \left[\left(\frac{(2.8761 \text{ ft})}{(15 \text{ ft})} + \frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.8761 \text{ ft})}{(15 \text{ ft})} + 3 \right) \times \left(\frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.8761 \text{ ft})}{(15 \text{ ft})} + 2 \right) \times \left(\frac{(10.971 \text{ ft})}{2 \times (15 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.4716 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.398 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.017 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.017 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(11.398\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.00909$$	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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.398\ \text{kip} \rightarrow 11398\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(11398\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$ $$V_{c,a} = 76.373\ \text{kip}$$ 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 $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\ \text{kip}), (76.373\ \text{kip}), (204.04\ \text{kip})\right]$$	

$$V_c = 76.373\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.373\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.453\ \text{kip}$$

Considering x-direction:

$V_{max} = 11.562\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.562\ \text{kip})}{(74.453\ \text{kip})}$$

$$Ratio = 0.1553$$

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

Considering z-direction:

$V_{max} = 0.23752\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.23752\ \text{kip})}{(74.453\ \text{kip})}$$

$$Ratio = 0.0031902$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$		
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ 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:** $M_{max} = 79\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(79\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 1.2736$$		Status: **FAIL** Ratio: **1.270**
	Considering z-direction: $M_{max} = 1.4716\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4716\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.023726$$		Status: **PASS** Ratio: **0.020**