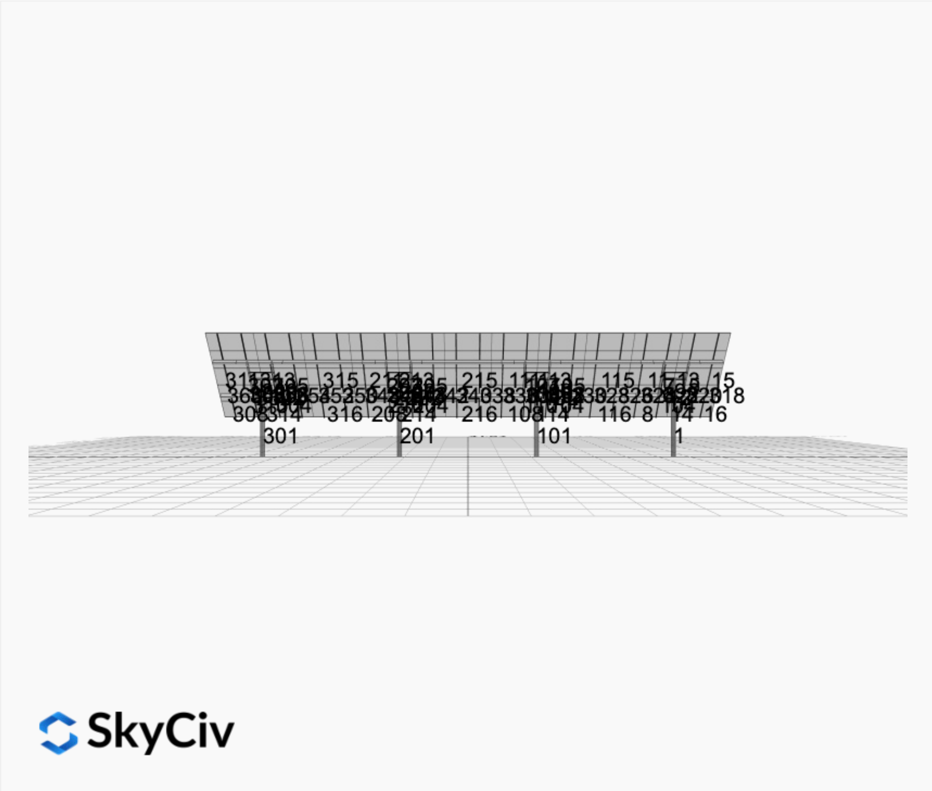
Project Details

Project Name: BT 40d CAN Sol 600 6h 46deg - V1Jb
Location: 31842 Frontage Rd, Bozeman, MT 59715, USA
Unique ID: 4P-22.5-8TOP-HD-45-L-5Hx11W-8ILH
Dealer: ______________________________

Date: Wed Jun 04 2025
Number of Modules: 55
Number of Poles: 4
Date Sold:
____



Array Dimensions N/S	18.79 ft
Array Dimensions E/W	83.14 ft
Winter Tilt Angle	46
Front Edge Clearance	6 ft

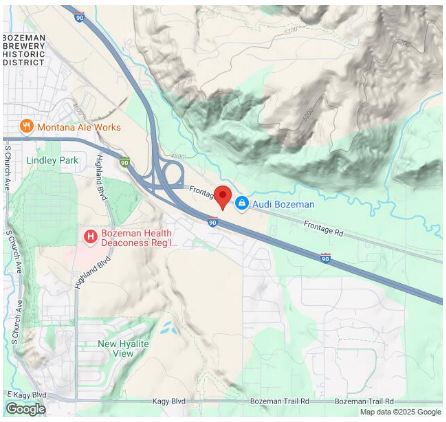
MT Solar Bill of Materials (4P-22.5-8TOP-HD-45-L-5Hx11W-8ILH)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-HD	H-Frame Assembly-HD	4
MTS-HD-Wing-45	45IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	12
MTS-CLAMP-ANGLE-4PK	Angle Clamp	11

Rail Bill of Materials

Part	Qty
Rails (226in)	22
Rail Attachment	88
Module Mid Clamp	88
Module End Clamp	44
Ground Lug	11

Site Details:



Site Address: 31842 Frontage Rd, Bozeman, MT 59715, USA

Array Specification

Duty Classification:	HD
Module Width:	44.60 in
Module Length:	89.70in
Number of Rows:	5
Number of Columns:	11
Total Number of Modules:	55
Winter Tilt Angle:	46
Front Edge Clearance:	6
Total Array Height at Tilt:	19.52 ft
Total Frame Length:	82.50 ft
Module Info/Notes:	TOPBiHiKu6 CS6W-600TB-AG
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	83.14 ft
Rail Length:	225.50 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	12.76 ft
Number of Poles:	4
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 8.00 ft Pile 3: 8.00 ft Pile 4: 7.50 ft
Foundation Volume:	18.370 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	31842 Frontage Rd, Bozeman, MT 59715, USA
Wind Speed:	115 mph

Snow Load:	51 psf

Design Disclaimer

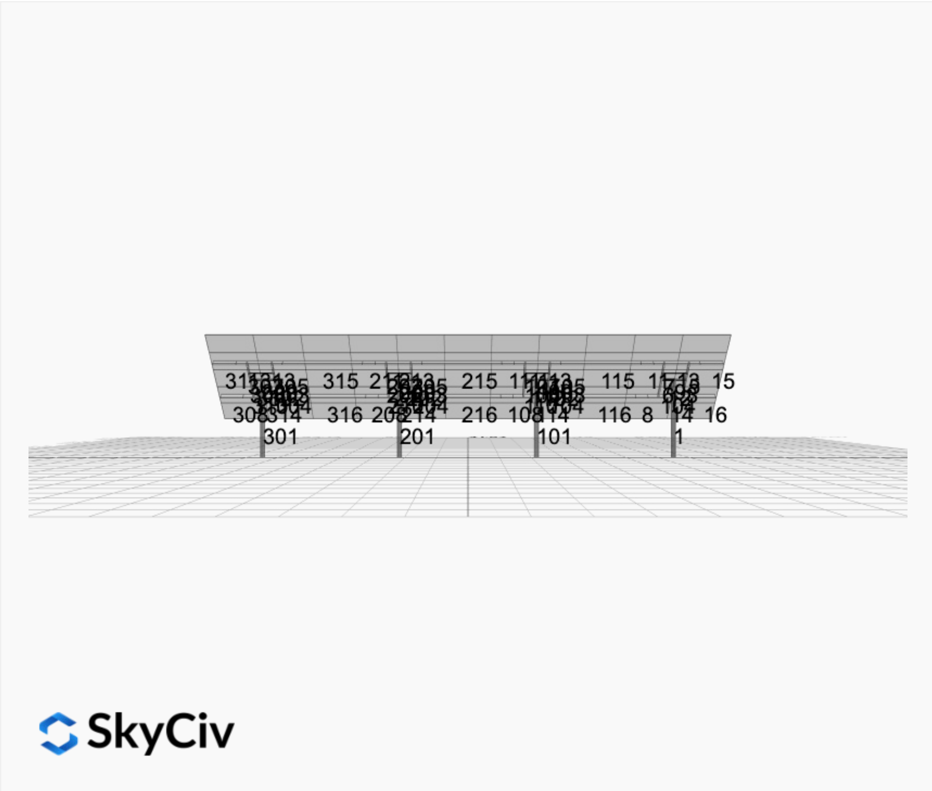
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

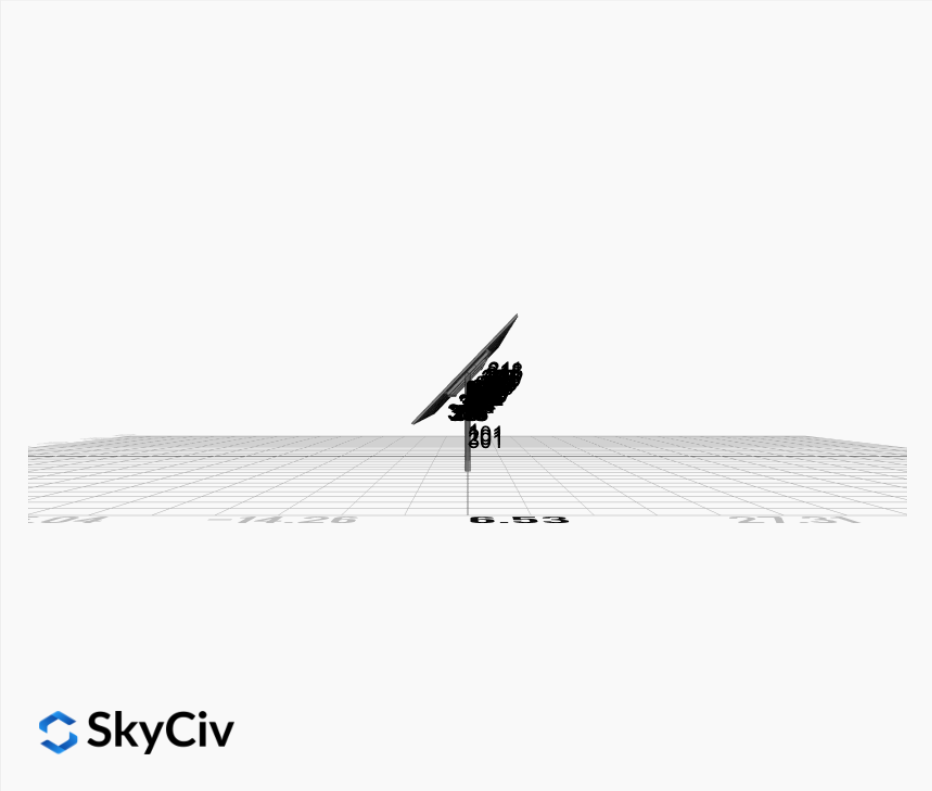
AutoDesigner Input

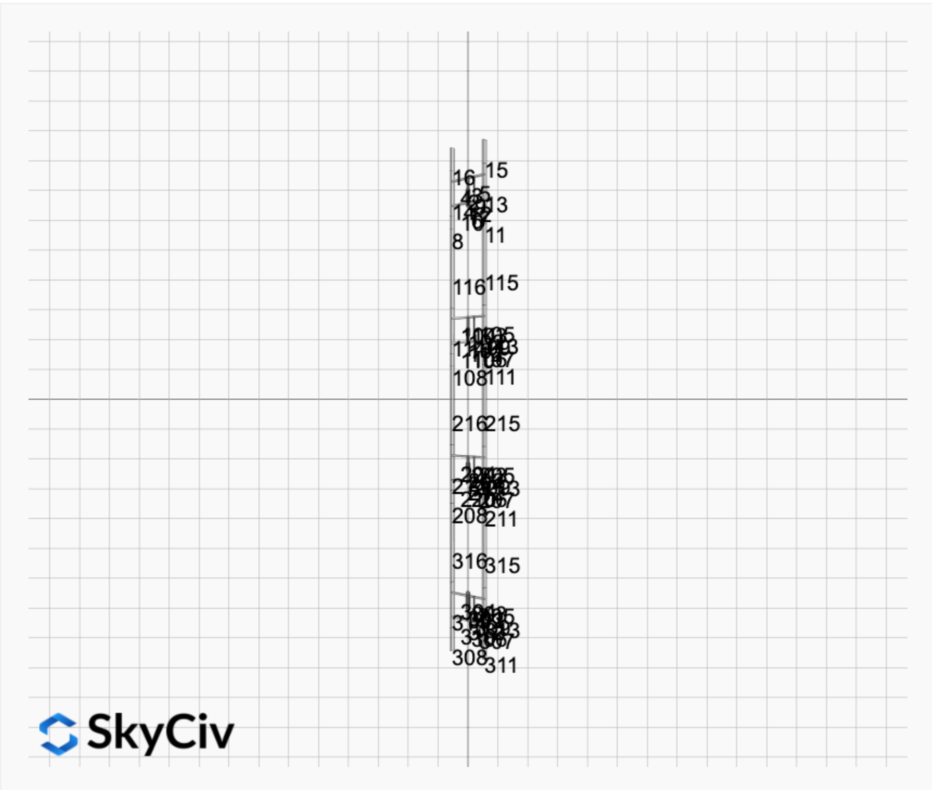
{"wind_speed_override":115,"snow_load_override":51,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Thomas Burney","designer_email":"thomas.burney@onsiteenergyinc.com","designer_phone":"","project_id":"BT 40d CAN Sol 600 6h 46deg - V1Jb","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_info":"TOPBiHiKu6 CS6W-600TB-AG","module_width":44.6,"module_length":89.7,"number_rows":"5","number_columns":11,"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":46,"ground_clearance":6,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

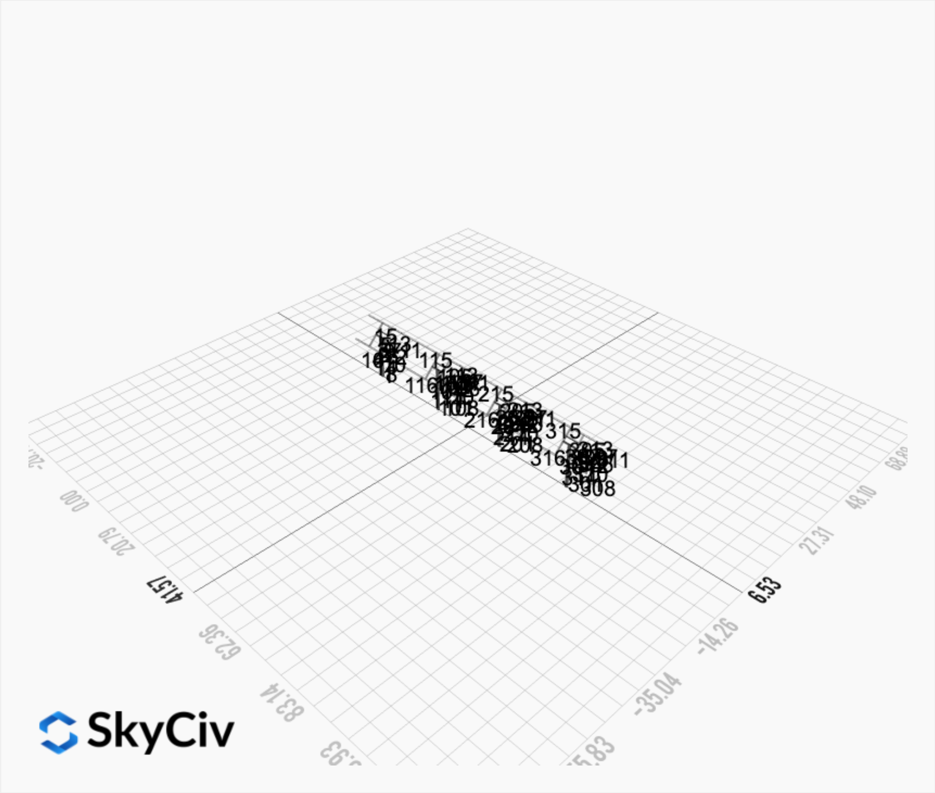
Design Notes:

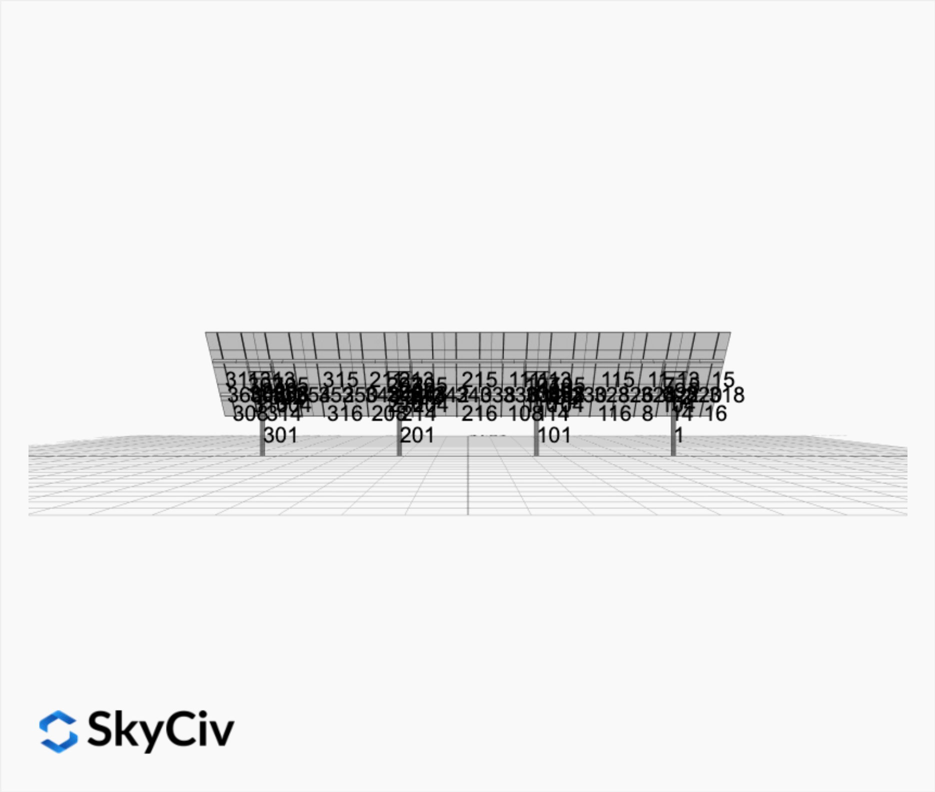
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



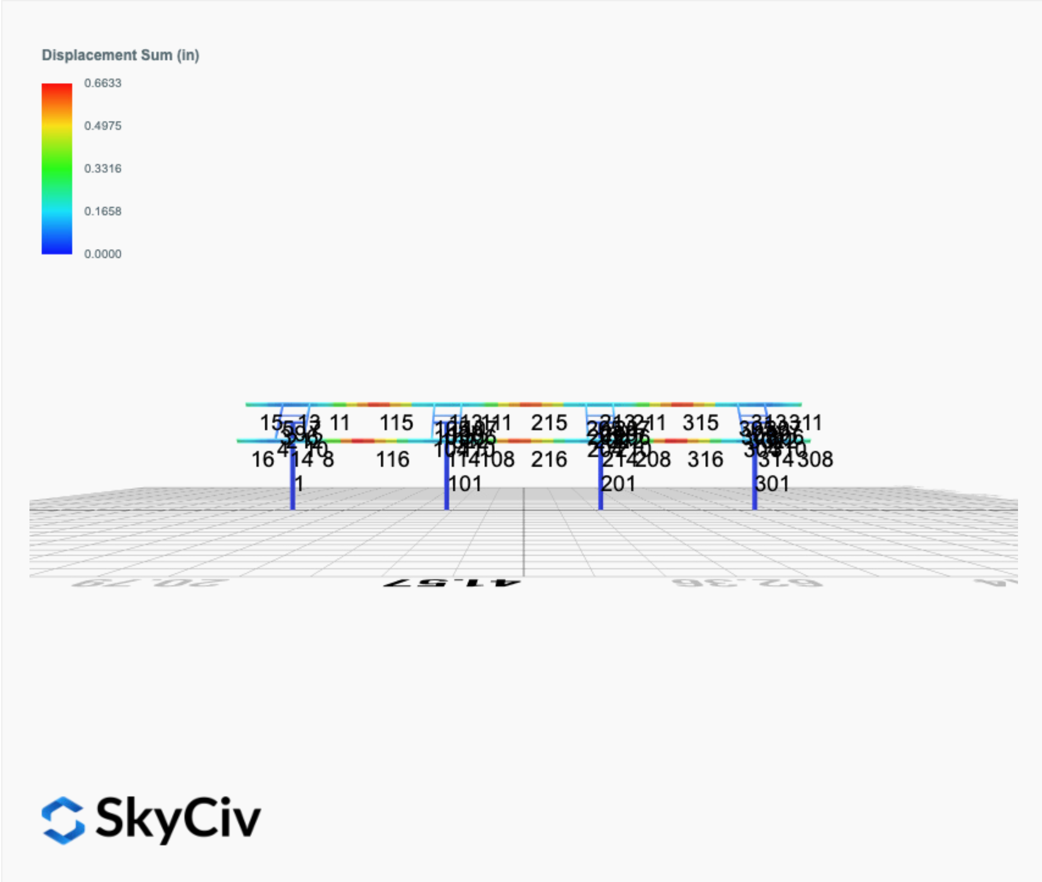

6.53
SkyCiv

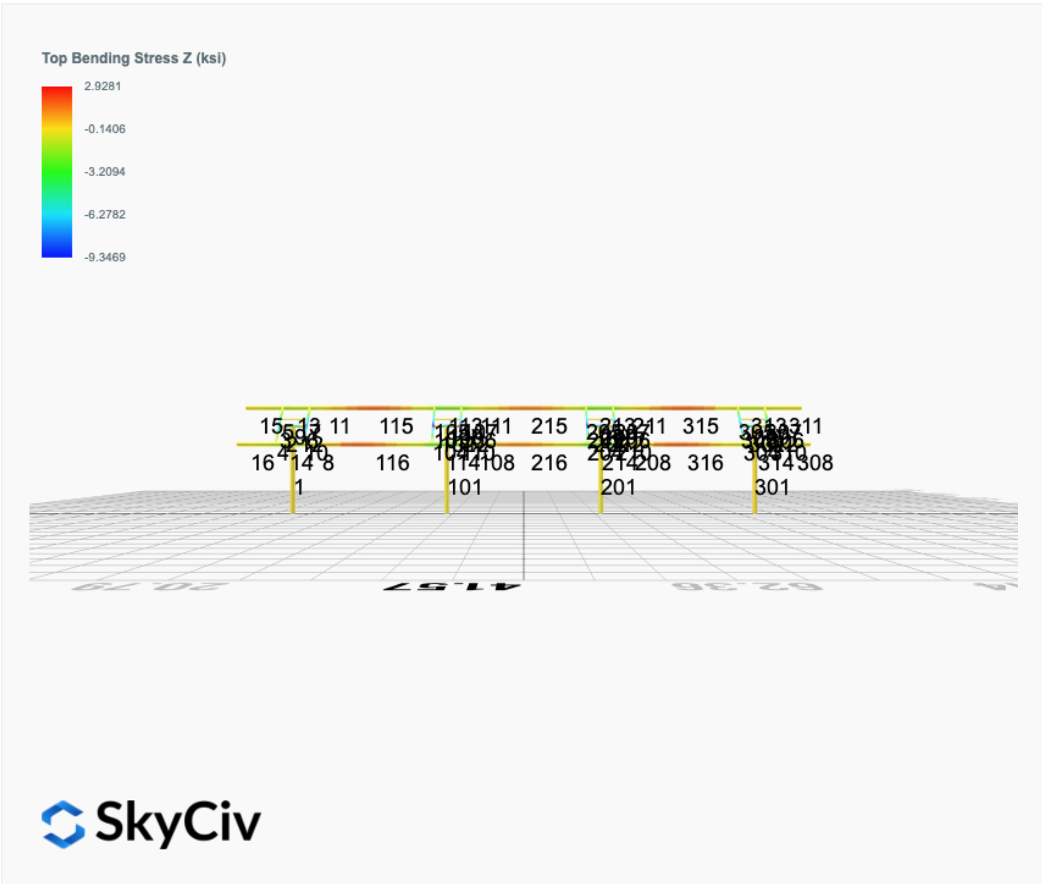

15
16
13
11
8
116
115
108
111
216
215
208
211
316
315
308
311
SkyCiv

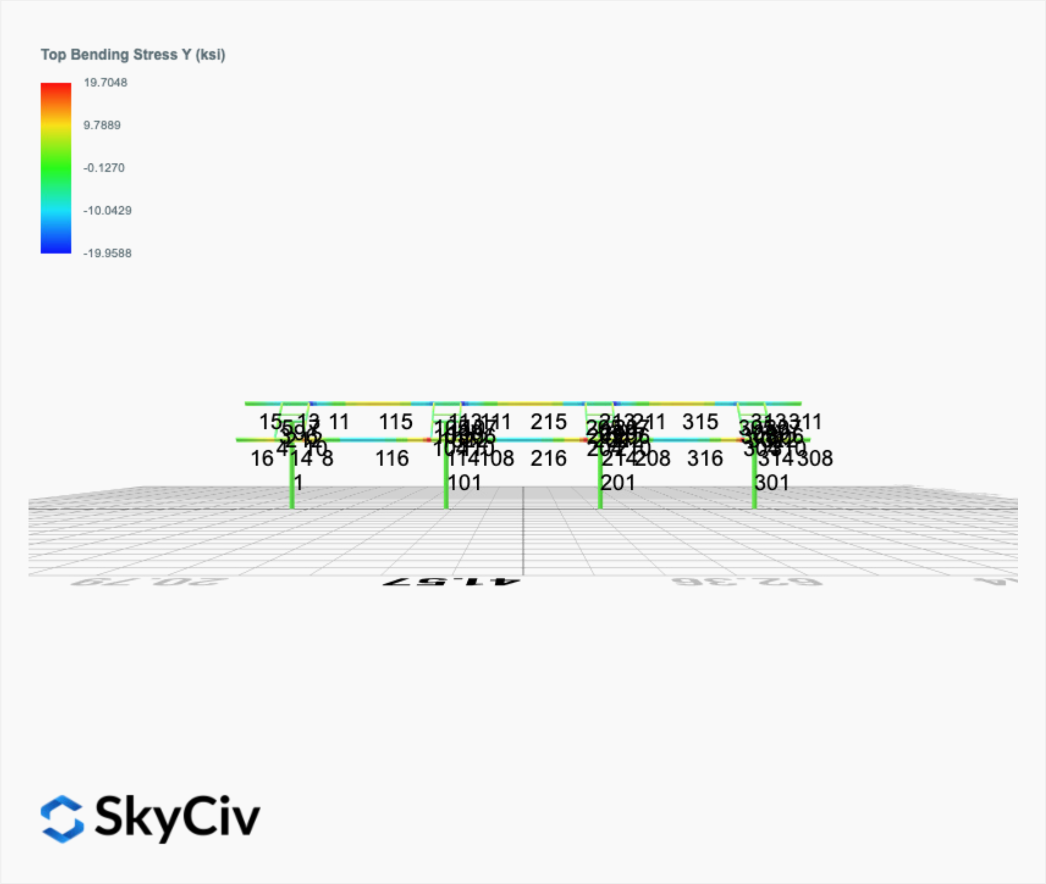


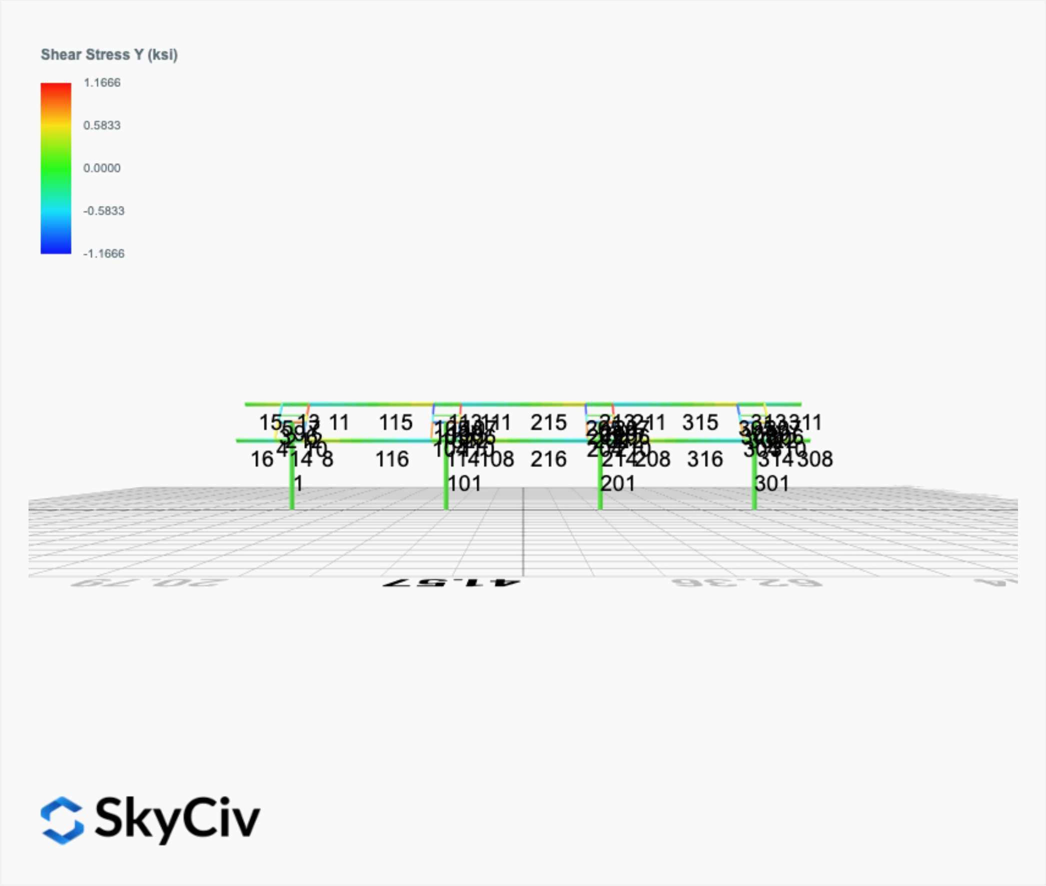


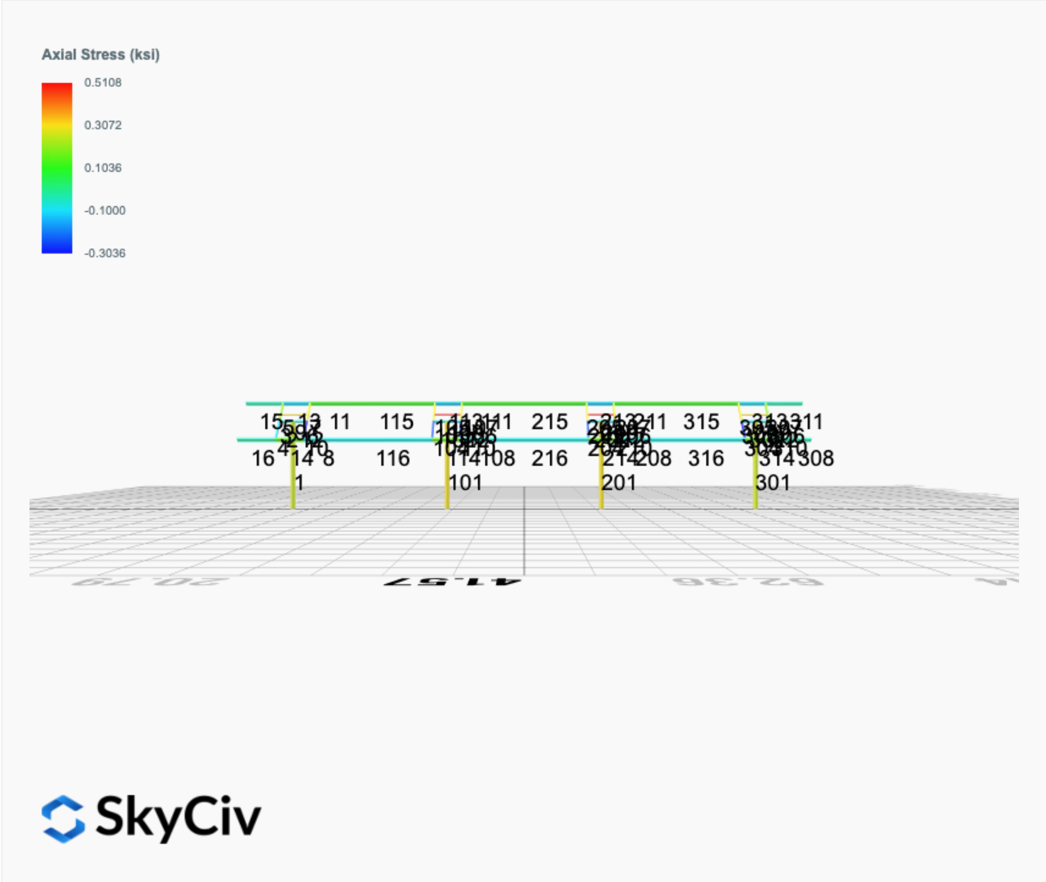
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
19.7048
9.7889
-0.1270
-10.0429
-19.9588
SkyCiv


Shear Stress Y (ksi)
1.1666
0.5833
0.0000
-0.5833
-1.1666
SkyCiv


Axial Stress (ksi)
0.5108
0.3072
0.1036
-0.1000
-0.3036
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	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 2. D + L	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 3. D + (S or Lr or R)	0.0611	5.9441	0.1876	0.7122	-0.2341	-0.7197
ULS: 3. D + (S or Lr or R)	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0515	5.1306	0.1581	0.6001	-0.1973	-0.6041
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 5b. D + 0.7E	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0515	5.1306	0.1581	0.6001	-0.1973	-0.6041
ULS: 8. 0.6D + 0.7E	0.0136	1.6141	0.0417	0.1581	-0.0520	-0.1543
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.3734	5.9387	0.2735	0.9860	-1.1831	43.8499
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4154	-0.5564	-0.1297	-0.4406	0.9856	-43.1060
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4956	7.5671	0.3111	1.1419	-1.0196	32.4763
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0515	5.1306	0.1581	0.6001	-0.1973	-0.6041
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5960	2.6957	0.0087	0.0719	0.6069	-32.7407
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0515	5.1306	0.1581	0.6001	-0.1973	-0.6041
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5244	5.1266	0.2225	0.8054	-0.9090	32.8232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5672	0.2552	-0.0799	-0.2646	0.7175	-32.3938
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0227	2.6901	0.0695	0.2636	-0.0867	-0.2572
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.3825	4.8627	0.2457	0.8806	-1.1484	43.9528
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0136	1.6141	0.0417	0.1581	-0.0520	-0.1543
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4064	-1.6325	-0.1575	-0.5461	1.0202	-43.0031
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0136	1.6141	0.0417	0.1581	-0.0520	-0.1543

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	11.1424
Shear X	-5.7030
Shear Z	0.4858
Moment X	1.7575
Moment Y (Twist)	2.0197
Moment Z	74.0191

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	7.5671
Shear X	-3.4154
Shear Z	0.3111
Moment X	1.1419
Moment Y (Twist)	1.1831
Moment Z	43.9528

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	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 2. D + L	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 3. D + (S or Lr or R)	-0.0611	7.1209	-0.0125	-0.0478	0.0643	0.8039
ULS: 3. D + (S or Lr or R)	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0515	6.1225	-0.0105	-0.0403	0.0542	0.6793

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 5b. D + 0.7E	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0515	6.1225	-0.0105	-0.0403	0.0542	0.6793
ULS: 8. 0.6D + 0.7E	-0.0136	1.8764	-0.0028	-0.0107	0.0143	0.1834
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1772	7.1703	0.0069	0.0191	-0.0770	54.0726
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.1352	-0.9177	-0.0136	-0.0455	0.1095	-51.7030
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1674	9.1547	-0.0019	-0.0126	-0.0215	41.0046
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0515	6.1225	-0.0105	-0.0403	0.0542	0.6793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0670	3.0888	-0.0172	-0.0611	0.1184	-38.3272
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0515	6.1225	-0.0105	-0.0403	0.0542	0.6793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1386	6.1596	0.0040	0.0099	-0.0518	40.6309
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0958	0.0936	-0.0114	-0.0386	0.0881	-38.7009
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0227	3.1274	-0.0047	-0.0178	0.0239	0.3056
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1682	5.9194	0.0088	0.0262	-0.0865	53.9504
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0136	1.8764	-0.0028	-0.0107	0.0143	0.1834
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.1443	-2.1686	-0.0117	-0.0384	0.0999	-51.8253
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0136	1.8764	-0.0028	-0.0107	0.0143	0.1834

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	13.5110
Shear X	-6.9682
Shear Z	-0.0275
Moment X	-0.0988
Moment Y (Twist)	0.2015
Moment Z	91.6795

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	9.1547
Shear X	-4.1772
Shear Z	-0.0172
Moment X	-0.0611
Moment Y (Twist)	0.1184
Moment Z	54.0726

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	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 2. D + L	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 3. D + (S or Lr or R)	-0.0611	7.1209	0.0125	0.0476	-0.0639	0.8039
ULS: 3. D + (S or Lr or R)	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0515	6.1225	0.0106	0.0401	-0.0539	0.6793
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 5b. D + 0.7E	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0515	6.1225	0.0106	0.0401	-0.0539	0.6793
ULS: 8. 0.6D + 0.7E	-0.0136	1.8764	0.0028	0.0106	-0.0143	0.1834
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1772	7.1703	-0.0069	-0.0191	0.0770	54.0726
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.1352	-0.9177	0.0136	0.0454	-0.1094	-51.7030
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056

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	-3.1674	9.1548	0.0019	0.0125	0.0217	41.0046
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0515	6.1225	0.0106	0.0401	-0.0539	0.6793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0670	3.0888	0.0173	0.0609	-0.1181	-38.3272
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0515	6.1225	0.0106	0.0401	-0.0539	0.6793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1386	6.1596	-0.0040	-0.0099	0.0518	40.6309
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0958	0.0936	0.0114	0.0385	-0.0880	-38.7009
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0227	3.1274	0.0047	0.0177	-0.0238	0.3056
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1682	5.9194	-0.0087	-0.0262	0.0866	53.9504
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0136	1.8764	0.0028	0.0106	-0.0143	0.1834
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.1443	-2.1686	0.0117	0.0384	-0.0999	-51.8253
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0136	1.8764	0.0028	0.0106	-0.0143	0.1834

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	13.5110
Shear X	-6.9682
Shear Z	0.0276
Moment X	0.0990
Moment Y (Twist)	0.2018
Moment Z	91.6796

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	9.1548
Shear X	-4.1772
Shear Z	0.0173
Moment X	0.0609
Moment Y (Twist)	0.1181
Moment Z	54.0726

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	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 2. D + L	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 3. D + (S or Lr or R)	0.0611	5.9441	-0.1876	-0.7127	0.2344	-0.7195
ULS: 3. D + (S or Lr or R)	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0515	5.1306	-0.1581	-0.6005	0.1975	-0.6039
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 5b. D + 0.7E	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0515	5.1306	-0.1581	-0.6005	0.1975	-0.6039
ULS: 8. 0.6D + 0.7E	0.0136	1.6141	-0.0417	-0.1582	0.0520	-0.1543
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.3734	5.9387	-0.2735	-0.9861	1.1831	43.8500
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4154	-0.5564	0.1297	0.4405	-0.9855	-43.1060
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4956	7.5671	-0.3111	-1.1423	1.0198	32.4765
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0515	5.1306	-0.1581	-0.6005	0.1975	-0.6039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5960	2.6957	-0.0087	-0.0723	-0.6067	-32.7405
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0515	5.1306	-0.1581	-0.6005	0.1975	-0.6039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5244	5.1266	-0.2225	-0.8055	0.9090	32.8232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5672	0.2552	0.0799	0.2645	-0.7175	-32.3938
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0227	2.6901	-0.0695	-0.2637	0.0867	-0.2572

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.3825	4.8627	-0.2457	-0.8806	1.1484	43.9528
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0136	1.6141	-0.0417	-0.1582	0.0520	-0.1543
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4064	-1.6325	0.1575	0.5460	-1.0202	-43.0031
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0136	1.6141	-0.0417	-0.1582	0.0520	-0.1543

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	11.1423
Shear X	-5.7030
Shear Z	-0.4858
Moment X	-1.7588
Moment Y (Twist)	2.0208
Moment Z	74.0207

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	7.5671
Shear X	-3.4154
Shear Z	-0.3111
Moment X	-1.1423
Moment Y (Twist)	1.1831
Moment Z	43.9528

Project Details

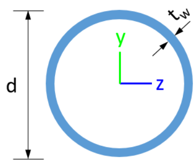
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

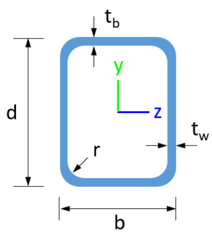
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

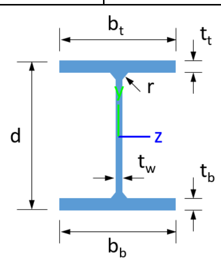
Section Dimensions



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	0.73	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	26.79	26.79	12.76	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.19,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
8	19	1.33	1.33	2.05	1.70,1.70,1.70,1.71,1.70,1.70,1.69,1.70,1.68,1.70,1.69,1.70,1.69,1.70,1.70,1.71,1.77,1.71,1.69,1.70,1.68,1.70,1.69,1.70,1.69,1.70	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
11	19	1.33	1.33	2.05	1.77,1.77,1.77,1.78,1.77,1.77,1.94,1.77,2.08,1.77,1.96,1.77,2.04,1.77,1.87,1.78,1.42,1.78,1.93,1.77,2.08,1.77,1.97,1.77,2.02,1.77	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.06,1.08,1.06,1.08,1.05,1.08,1.07,1.08,1.15,1.08,1.06,1.08,1.07,1.08,1.06,1.08,1.06,1.08	300	200	1
14	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08,1.07,1.08,1.10,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08	300	200	1
15	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	26.79	26.79	12.76	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
105	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
106	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
108	19	1.33	1.33	2.05	2.24,2.24,2.24,2.23,2.24,2.24,2.25,2.24,2.27,2.24,2.25,2.24,2.26,2.24,2.24,2.23,2.00,2.23,2.25,2.24,2.27,2.24,2.25,2.24,2.26,2.24	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
111	19	1.33	1.33	2.05	2.25,2.25,2.25,2.25,2.25,2.25,2.34,2.25,2.13,2.25,2.35,2.25,2.17,2.25,2.30,2.25,1.55,2.25,2.33,2.25,2.12,2.25,2.35,2.25,2.24,2.25	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03	300	200	1
114	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.04,1.03	300	200	1
115	19	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.13,1.17,1.14,1.17,1.14,1.17,1.15,1.17,1.27,1.17,1.15,1.17,1.12,1.17,1.14,1.17,1.14,1.17	300	200	1
116	19	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.20,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.17,1.17	300	200	1
201	10	26.79	26.79	12.76	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
205	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
206	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
208	19	1.33	1.33	2.05	2.30,2.30,2.30,2.30,2.30,2.30,2.33,2.30,2.35,2.30,2.34,2.30,2.35,2.30,2.32,2.30,2.22,2.30,2.33,2.30,2.31,2.30,2.34,2.30,2.35,2.30	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
211	19	1.33	1.33	2.05	2.33,2.33,2.33,2.33,2.33,2.33,2.12,2.33,2.03,2.33,2.11,2.33,2.09,2.33,2.14,2.33,1.62,2.33,2.12,2.33,1.94,2.33,2.11,2.33,2.09,2.33	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03	300	200	1
214	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.04,1.03	300	200	1
215	19	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.15,1.18,1.16,1.18,1.15,1.18,1.17,1.18,1.59,1.18,1.16,1.18,1.14,1.18,1.16,1.18,1.15,1.18	300	200	1
216	19	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18	300	200	1
301	10	26.79	26.79	12.76	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
306	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.19,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
308	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
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
311	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
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.06,1.08,1.06,1.08,1.05,1.08,1.07,1.08,1.16,1.08,1.06,1.08,1.07,1.08,1.06,1.08,1.05,1.08	300	200	1
314	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08,1.07,1.08,1.10,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08	300	200	1

315	19	8.42	8.42	12.95	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.13,1.12	300	200	1
316	19	8.42	8.42	12.95	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12	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	230.60	123.94	123.94	172.30	172.30
2	198.33	196.72	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	123.95	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	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	24.15	6.12	40.24	43.62
14	133.20	85.85	24.31	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	230.60	123.94	123.94	172.30	172.30
102	198.33	196.72	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	123.95	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	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.68	6.12	40.24	43.62
114	133.20	85.85	23.65	6.12	40.24	43.62
115	133.20	46.28	12.18	6.12	40.24	43.62
116	133.20	46.28	12.59	6.12	40.24	43.62
201	574.32	230.60	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	123.95	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	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50

212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.68	6.12	40.24	43.62
214	133.20	85.85	23.65	6.12	40.24	43.62
215	133.20	46.28	12.39	6.12	40.24	43.62
216	133.20	46.28	12.68	6.12	40.24	43.62
301	574.32	230.60	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	52.83	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	52.83	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	24.14	6.12	40.24	43.62
314	133.20	85.85	24.32	6.12	40.24	43.62
315	133.20	46.28	12.14	6.12	40.24	43.62
316	133.20	46.28	12.11	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	0.048	0.597	0.036	0.033	0.003	0.634	#13	0.559	Not Required	Pass
2	0.006	0.278	0.208	0.070	0.042	0.469	#13	0.035	Not Required	Pass
3	0.009	0.533	0.055	0.052	0.010	0.547	#13	0.045	Not Required	Pass
4	0.009	0.535	0.174	0.054	0.038	0.626	#13	0.080	Not Required	Pass
5	0.009	0.331	0.159	0.053	0.042	0.351	#13	0.074	Not Required	Pass
6	0.015	0.746	0.112	0.076	0.021	0.814	#13	0.045	Not Required	Pass
7	0.016	0.463	0.291	0.074	0.072	0.501	#13	0.074	Not Required	Pass
8	0.005	0.097	0.310	0.050	0.025	0.314	#23	0.095	Not Required	Pass
9	0.021	0.061	0.096	0.004	0.004	0.155	#13	0.204	Not Required	Pass
10	0.016	0.719	0.277	0.072	0.058	0.772	#13	0.080	Not Required	Pass
11	0.006	0.086	0.321	0.052	0.025	0.327	#23	0.095	Not Required	Pass
12	0.004	0.461	0.300	0.106	0.057	0.761	#13	0.053	Not Required	Pass
13	0.008	0.214	0.675	0.064	0.031	0.821	#21	0.286	Not Required	Pass
14	0.010	0.204	0.660	0.062	0.031	0.784	#21	0.190	Not Required	Pass
15	0.000	0.061	0.168	0.027	0.013	0.221	#21	Not Required	Not Required	Pass
16	0.000	0.061	0.168	0.027	0.013	0.221	#21	Not Required	Not Required	Pass
101	0.059	0.740	0.002	0.040	0.000	0.767	#13	0.559	Not Required	Pass
102	0.007	0.457	0.316	0.108	0.058	0.759	#13	0.035	Not Required	Pass
103	0.015	0.774	0.073	0.077	0.002	0.818	#13	0.045	Not Required	Pass
104	0.015	0.788	0.285	0.079	0.059	0.892	#13	0.080	Not Required	Pass
105	0.015	0.480	0.302	0.077	0.077	0.524	#13	0.074	Not Required	Pass
106	0.015	0.790	0.073	0.079	0.003	0.829	#13	0.045	Not Required	Pass
107	0.015	0.491	0.294	0.078	0.075	0.535	#13	0.074	Not Required	Pass
108	0.005	0.080	0.304	0.053	0.025	0.375	#21	0.095	Not Required	Pass
109	0.030	0.057	0.068	0.001	0.000	0.132	#13	0.204	Not Required	Pass
110	0.014	0.785	0.279	0.079	0.058	0.880	#13	0.080	Not Required	Pass

111	0.006	0.066	0.314	0.053	0.025	0.378	#21	0.095	Not Required	Pass
112	0.007	0.454	0.322	0.108	0.059	0.770	#13	0.035	Not Required	Pass
113	0.008	0.282	0.683	0.067	0.031	0.914	#21	0.286	Not Required	Pass
114	0.013	0.314	0.673	0.069	0.031	0.921	#21	0.286	Not Required	Pass
115	0.015	0.547	0.365	0.055	0.025	0.838	#21	0.601	Not Required	Pass
116	0.006	0.534	0.360	0.057	0.025	0.818	#21	0.601	Not Required	Pass
201	0.059	0.740	0.002	0.040	0.000	0.767	#13	0.559	Not Required	Pass
202	0.007	0.454	0.322	0.107	0.059	0.770	#13	0.035	Not Required	Pass
203	0.015	0.790	0.073	0.079	0.003	0.829	#13	0.045	Not Required	Pass
204	0.014	0.785	0.279	0.079	0.058	0.880	#13	0.080	Not Required	Pass
205	0.015	0.491	0.294	0.078	0.075	0.535	#13	0.074	Not Required	Pass
206	0.015	0.774	0.073	0.077	0.002	0.818	#13	0.045	Not Required	Pass
207	0.015	0.480	0.302	0.077	0.077	0.524	#13	0.074	Not Required	Pass
208	0.005	0.070	0.320	0.057	0.025	0.383	#21	0.095	Not Required	Pass
209	0.030	0.057	0.068	0.001	0.000	0.132	#13	0.204	Not Required	Pass
210	0.015	0.788	0.285	0.079	0.059	0.892	#13	0.080	Not Required	Pass
211	0.006	0.069	0.329	0.055	0.025	0.382	#21	0.095	Not Required	Pass
212	0.007	0.457	0.316	0.108	0.058	0.759	#13	0.035	Not Required	Pass
213	0.008	0.282	0.684	0.067	0.031	0.914	#21	0.286	Not Required	Pass
214	0.013	0.314	0.673	0.069	0.031	0.921	#21	0.286	Not Required	Pass
215	0.016	0.464	0.365	0.053	0.025	0.757	#21	0.601	Not Required	Pass
216	0.007	0.421	0.359	0.053	0.025	0.719	#21	0.601	Not Required	Pass
301	0.048	0.597	0.036	0.033	0.003	0.634	#13	0.559	Not Required	Pass
302	0.004	0.461	0.300	0.106	0.057	0.761	#13	0.053	Not Required	Pass
303	0.015	0.746	0.112	0.076	0.021	0.814	#13	0.045	Not Required	Pass
304	0.016	0.719	0.277	0.072	0.058	0.772	#13	0.080	Not Required	Pass
305	0.016	0.463	0.291	0.074	0.072	0.501	#13	0.074	Not Required	Pass
306	0.009	0.533	0.055	0.052	0.010	0.547	#13	0.045	Not Required	Pass
307	0.009	0.331	0.159	0.053	0.042	0.351	#13	0.074	Not Required	Pass
308	0.000	0.061	0.168	0.027	0.013	0.221	#21	Not Required	Not Required	Pass
309	0.021	0.061	0.096	0.004	0.005	0.155	#13	0.204	Not Required	Pass
310	0.009	0.535	0.174	0.054	0.038	0.626	#13	0.080	Not Required	Pass
311	0.000	0.061	0.168	0.027	0.013	0.221	#21	Not Required	Not Required	Pass
312	0.006	0.278	0.208	0.070	0.042	0.469	#13	0.035	Not Required	Pass
313	0.008	0.214	0.674	0.064	0.031	0.821	#21	0.190	Not Required	Pass
314	0.010	0.204	0.661	0.062	0.031	0.784	#21	0.286	Not Required	Pass
315	0.015	0.553	0.366	0.052	0.025	0.843	#21	0.601	Not Required	Pass
316	0.006	0.553	0.358	0.050	0.025	0.828	#21	0.601	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

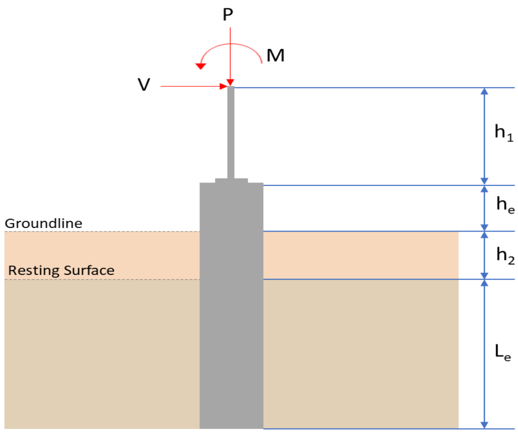
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 7.5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.567	11.142
V_x (kip)	-3.415	-5.703
V_z (kip)	0.311	0.486
M_x (kipft)	1.142	1.757
M_z (kipft)	43.953	74.019

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.415 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.54379 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(43.953\ \mathrm{kipft}) + ((-3.415\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.999\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.9356\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.311\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.049522\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.142\ \mathrm{kipft}) + ((0.311\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.18185\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.8438\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.9356\ \mathrm{ft}), (2.8438\ \mathrm{ft})]$$

$$L_{e,req} = 6.936\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.936\ \mathrm{ft})}{(7.5\ \mathrm{ft})}$$

$$Ratio = 0.9248$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.567\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.47294\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.47294\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23647$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.54379\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.999\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.999\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.999\ \mathrm{kipft/ft})) + (4 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1749\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.999\ \mathrm{kipft/ft})) + (3 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.999\ \mathrm{kipft/ft})) + (2 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.25793\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.999\ \mathrm{kipft/ft})) + ((-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0581\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1749\ \mathrm{ft})}{2}$$

$$p_a = 0.38812\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.25793\ \mathrm{kip/ft^2}\right)}{\left(0.38812\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.66458$$	Status: **PASS** Ratio: **0.660**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$ $$p_s = 1.125\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.0581\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.9405$$	Status: **PASS** Ratio: **0.940**

Considering z-direction:

$H_o = 0.049522\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.18185\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18185\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.049522\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.18185\ \mathrm{kipft/ft})) + (4 \times (0.049522\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3604\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.18185\ \mathrm{kipft/ft})) + (3 \times (0.049522\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.18185\ \mathrm{kipft/ft})) + (2 \times (0.049522\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0351\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.18185\ \mathrm{kipft/ft})) + ((0.049522\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.078412\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3604\ \mathrm{ft})}{2}$$

$$p_a = 0.40203\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0351\ \mathrm{kip/ft^2}\right)}{\left(0.40203\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.087307$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

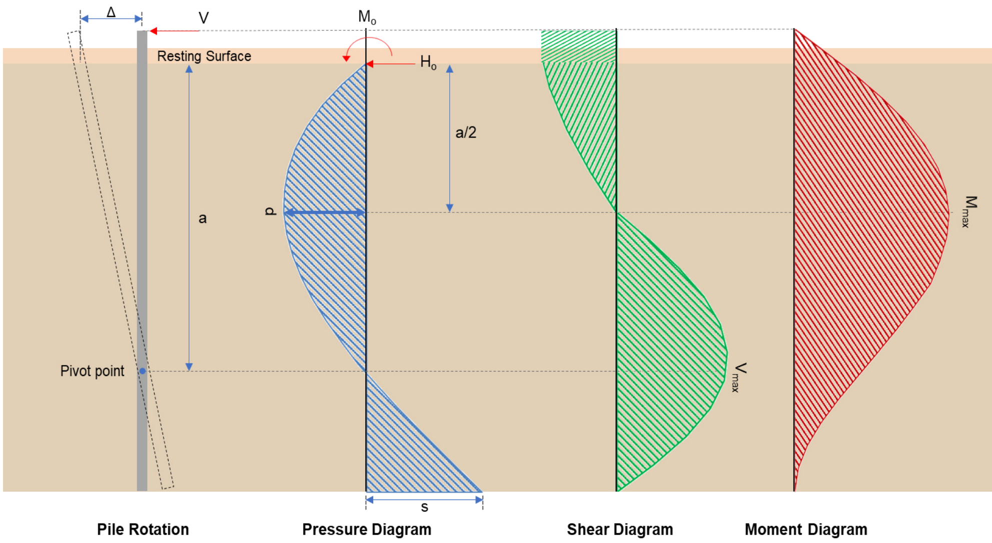
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.078412\ \text{kip/ft}^2\right)}{\left(1.125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.0697$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.703\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.90812\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(74.019\ \text{kipft}) + ((-5.703\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 11.786\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.786\ \text{kipft/ft})}{(-0.90812\ \text{kip/ft})}$$

$$E = 12.979\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.786\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.90812\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (11.786\ \mathrm{kipft/ft})) + (4 \times (-0.90812\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1738\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.90812\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.979\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1738\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.979\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1738\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.519\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.90812\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.5\ \mathrm{ft})) \times \left[\left(\frac{(12.979\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + \frac{(5.1738\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (12.979\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1738\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.979\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1738\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 48.223\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.486\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.077389\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.757\ \mathrm{kipft}) + ((0.486\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.27978\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.27978\ \mathrm{kipft/ft})}{(0.077389\ \mathrm{kip/ft})}$$

$$E = 3.6152\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.27978\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.077389\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.27978\ \mathrm{kipft/ft})) + (4 \times (0.077389\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3627\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.077389\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.6152\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3627\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.6152\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3627\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.4704\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.077389\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.5\ \mathrm{ft})) \times \left[\left(\frac{(3.6152\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + \frac{(5.3627\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.6152\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3627\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.6152\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3627\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.557\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.142\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.226\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.226\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.142\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0041649$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.142 \text{ kip} \rightarrow 11142 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11142 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.97 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.97 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.97 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.06 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.519 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(13.519\ \text{kip})}{(111.06\ \text{kip})}$$ $$Ratio = 0.12173$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $V_{max} = 0.4704\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.4704\ \text{kip})}{(111.06\ \text{kip})}$$ $$Ratio = 0.0042354$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 48.223\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(48.223\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.1932$$	Status: **PASS** Ratio: **0.190**
	Considering z-direction: $M_{max} = 1.557\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.557 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.006238$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

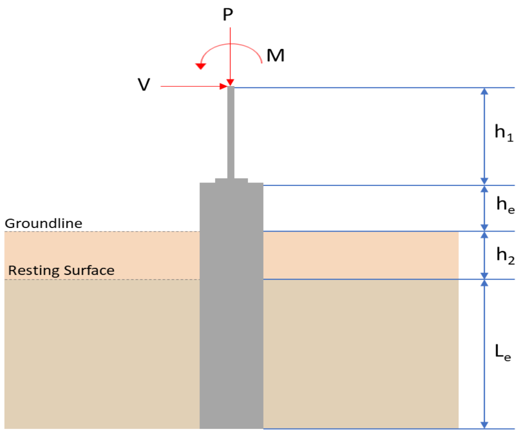
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 7.5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.567	11.142
V_x (kip)	-3.415	-5.703
V_z (kip)	-0.311	-0.486
M_x (kipft)	-1.142	-1.759
M_z (kipft)	43.953	74.021

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.415 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.54379 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(43.953 \text{ kipft}) + ((-3.415 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.999 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.9356 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.311 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.049522 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.142 \text{ kipft}) + ((-0.311 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.18185 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.0398 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.9356 \text{ ft}), (2.0398 \text{ ft})]$$

$$L_{e,req} = 6.936 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.936 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.9248$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.567\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.47294\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.47294\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23647$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.54379\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.999\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.999\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.999\ \mathrm{kipft/ft})) + (4 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1749\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.999\ \mathrm{kipft/ft})) + (3 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.999\ \mathrm{kipft/ft})) + (2 \times (-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.25793\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.999\ \mathrm{kipft/ft})) + ((-0.54379\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0581\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1749\ \mathrm{ft})}{2}$$

$$p_a = 0.38812\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25793 \text{ kip/ft}^2\right)}{\left(0.38812 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.66458$$

Status: **PASS**
Ratio: **0.660**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0581 \text{ kip/ft}^2\right)}{\left(1.125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.9405$$

Status: **PASS**
Ratio: **0.940**

Considering z-direction:

$H_o = -0.049522 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.18185 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18185 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.049522 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.18185 \text{ kipft/ft})) + (4 \times (-0.049522 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3604 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.18185 \text{ kipft/ft})) + (3 \times (-0.049522 \text{ kip/ft}) \times (7.5 \text{ ft}))]^{\,2}}{(7.5 \text{ ft})^2 \times [(3 \times (0.18185 \text{ kipft/ft})) + (2 \times (-0.049522 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = -0.010114 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.18185 \text{ kipft/ft})) + ((-0.049522 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = -0.00082378 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3604 \text{ ft})}{2}$$

$$p_a = 0.40203 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.010114 \text{ kip/ft}^2\right)}{\left(0.40203 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.025159$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

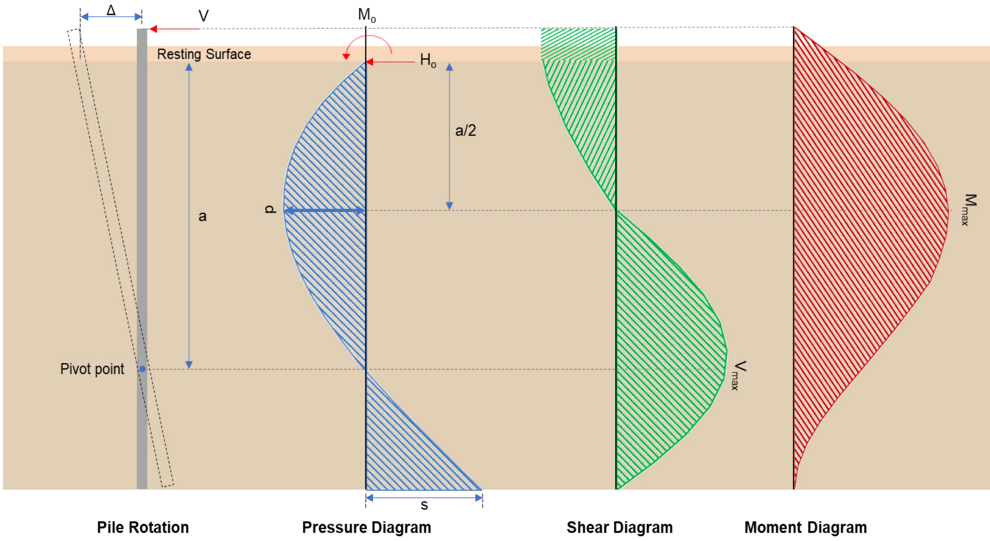
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00082378\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00073225$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.703\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.90812\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(74.021\ \mathrm{kipft}) + ((-5.703\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.787\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.787\ \mathrm{kipft/ft})}{(-0.90812\ \mathrm{kip/ft})}$$

$$E = 12.979\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.787\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.90812\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (11.787\ \text{kipft/ft})) + (4 \times (-0.90812\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1738\ \text{ft}$$

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

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

$$V_{max} = ((-0.90812\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.979\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1738\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.979\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1738\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.52\ \text{kip}$$

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

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

$$M_{max} = ((-0.90812\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(12.979\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.1738\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.979\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1738\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.979\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1738\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 48.225\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.486\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.077389\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.759\ \text{kipft}) + ((-0.486\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2801\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2801\ \text{kipft/ft})}{(-0.077389\ \text{kip/ft})}$$

$$E = 3.6193\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2801\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.077389\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.2801\ \text{kipft/ft})) + (4 \times (-0.077389\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.3626\ \text{ft}$$

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

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

$$V_{max} = ((-0.077389\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.6193\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.3626\text{ ft})}{(7.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.6193\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.3626\text{ ft})}{(7.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.47069\text{ kip}$$

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

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

$$M_{max} = ((-0.077389\text{ kip/ft}) \times (48\text{ in}) \times (7.5\text{ ft})) \times \left[\left(\frac{(3.6193\text{ ft})}{(7.5\text{ ft})} + \frac{(5.3626\text{ ft})}{2 \times (7.5\text{ ft})}\right) - \left[\left(\frac{4 \times (3.6193\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.3626\text{ ft})}{2 \times (7.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.6193\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.3626\text{ ft})}{2 \times (7.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.5581\text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.142\text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\text{ ksi}) \times (2304\text{ in}^2))}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, (0.08 \times (2304\text{ in}^2))\right]$$

$$A_{st,required} = -84.226\text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.226\text{ in}^2), (0.0018 \times (2304\text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.142\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0041649$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.142 \text{ kip} \rightarrow 11142 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11142 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.97 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.97 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.97 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.06 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.52 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(13.52\ \text{kip})}{(111.06\ \text{kip})}$$ $$Ratio = 0.12173$$	Status: **PASS** Ratio: **0.120**
	Considering z-direction: $V_{max} = 0.47069\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.47069\ \text{kip})}{(111.06\ \text{kip})}$$ $$Ratio = 0.0042381$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 48.225\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(48.225\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.19321$$	Status: **PASS** Ratio: **0.190**
	Considering z-direction: $M_{max} = 1.5581\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.5581 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0062425$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

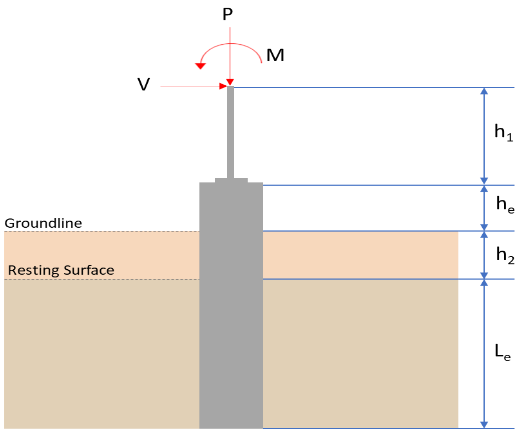
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.155	13.511
V_x (kip)	-4.177	-6.968
V_z (kip)	-0.017	-0.028
M_x (kipft)	-0.061	-0.099
M_z (kipft)	54.073	91.679

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.177\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.66513\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.073\ \text{kipft}) + ((-4.177\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.6104\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.3423\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.017\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.002707\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.061\ \text{kipft}) + ((-0.017\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0097134\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.86038\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3423\ \text{ft}), (0.86038\ \text{ft})]$$

$$L_{e,req} = 7.342\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.342\ \text{ft})}{(8\ \text{ft})}$$

$$Ratio = 0.91775$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

	$$q = \frac{P_v}{A}$$ $$q = \frac{(9.155\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$ $$q = 0.57219\ \mathrm{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{\left(0.57219\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$ $$Ratio = 0.28609$$		Status: **PASS** Ratio: **0.290**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(8\ \mathrm{ft})}{(48\ \mathrm{in})}$$ $$L/D = 2$$ Since L/D $\leq$ 10, Pile is short. **Considering x-direction:** $H_o = -0.66513\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 8.6104\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (8.6104\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.66513\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (8.6104\ \mathrm{kipft/ft})) + (4 \times (-0.66513\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$ $$a = 5.5279\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (8.6104\ \mathrm{kipft/ft})) + (3 \times (-0.66513\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^2}{(8\ \mathrm{ft})^2 \times [(3 \times (8.6104\ \mathrm{kipft/ft})) + (2 \times (-0.66513\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$ $$p = 0.26344\ \mathrm{kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (8.6104\ \mathrm{kipft/ft})) + ((-0.66513\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$ $$s = 1.1156\ \mathrm{kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5279\ \mathrm{ft})}{2}$$ $$p_a = 0.41459\ \mathrm{kip/ft}^2$$ $Ratio$ - Lateral soil capacity		

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.26344\ \mathrm{kip/ft^2}\right)}{\left(0.41459\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.63542$$	Status: **PASS** Ratio: **0.640**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$ $$p_s = 1.2\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1156\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92966$$	Status: **PASS** Ratio: **0.930**
	Considering z-direction: $H_o = -0.002707\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.0097134\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.0097134\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.0097134\ \mathrm{kipft/ft})) + (4 \times (-0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$ $$a = 5.7319\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.0097134\ \mathrm{kipft/ft})) + (3 \times (-0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.0097134\ \mathrm{kipft/ft})) + (2 \times (-0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$ $$p = -0.00056392\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.0097134\ \mathrm{kipft/ft})) + ((-0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$ $$s = -0.000209\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7319\ \mathrm{ft})}{2}$$ $$p_a = 0.42989\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.00056392\ \mathrm{kip/ft^2}\right)}{\left(0.42989\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = -0.0013118$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

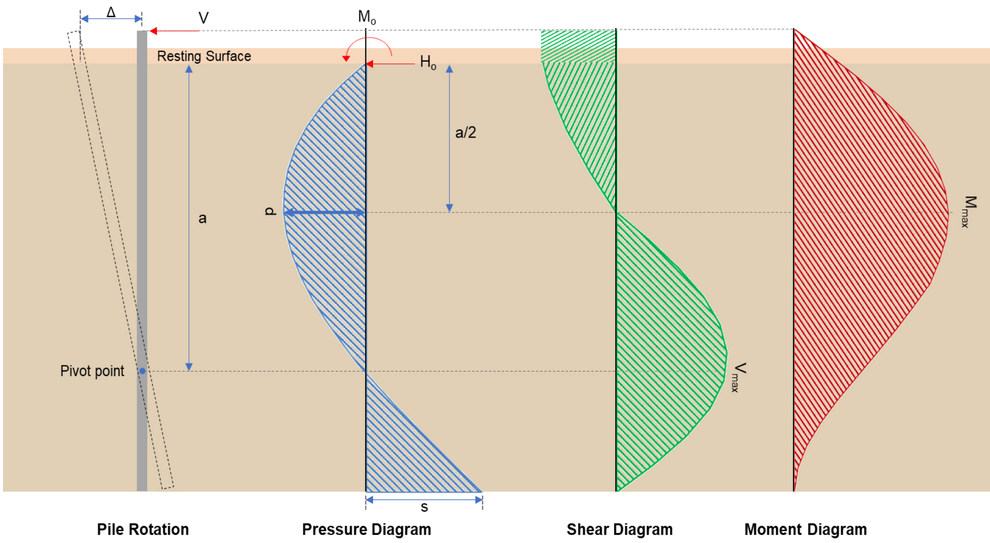
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.000209\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00017416$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.968\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1096\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(91.679\ \mathrm{kipft}) + ((-6.968\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.599\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.599\ \mathrm{kipft/ft})}{(-1.1096\ \mathrm{kip/ft})}$$

$$E = 13.157\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.599\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.1096\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (14.599\ \mathrm{kipft/ft})) + (4 \times (-1.1096\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5256\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1096\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.843\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1096\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 60.15\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.028\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0044586\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.099\ \mathrm{kipft}) + ((-0.028\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.015764\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015764\ \mathrm{kipft/ft})}{(-0.0044586\ \mathrm{kip/ft})}$$

$$E = 3.5357\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015764\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.0044586\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.015764\ \mathrm{kipft/ft})) + (4 \times (-0.0044586\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7342\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0044586\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5357\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7342\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5357\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7342\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.025853\ \text{kip}$$

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

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

$$M_{max} = ((-0.0044586\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(3.5357\ \text{ft})}{(8\ \text{ft})} + \frac{(5.7342\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.5357\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7342\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5357\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7342\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.090705\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.511\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.147\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.147\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	Status: PASS Ratio: 0.970
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$ $$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\text{ in}))\right]$$ $$s_{rebar} = 1.5\text{ in}$$	
	Ties:	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\text{ in})), (48 \times (0.375\text{ in})), Min\,((48\text{ in}), (48\text{ in}))\right]$$ $$s_{ties} = 10\text{ in}$$	
	Summary: Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.511\text{ kip})}{(2675.2\text{ kip})}$$ $$Ratio = 0.0050505$$	Status: PASS Ratio: 0.010
	Shear Strength (ACI 318-19, LRFD)	
	Parameters:	
22.5.2.2	$b_w = 48\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\text{ in})$$ $$d = 38.4\text{ in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$	
22.5.5.1.1	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.511\ \text{kip} \rightarrow 13511\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13511\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.29\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.29\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.29\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.29\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.27\ \text{kip}$$

Considering x-direction:

$V_{max} = 15.843\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(15.843 \text{ kip})}{(111.27 \text{ kip})}$$ $$Ratio = 0.14239$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.025853 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.025853 \text{ kip})}{(111.27 \text{ kip})}$$ $$Ratio = 0.00023235$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 60.15 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(60.15 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.24099$$	Status: **PASS** Ratio: **0.240**
	Considering z-direction: $M_{max} = 0.090705 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.090705\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0003634$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

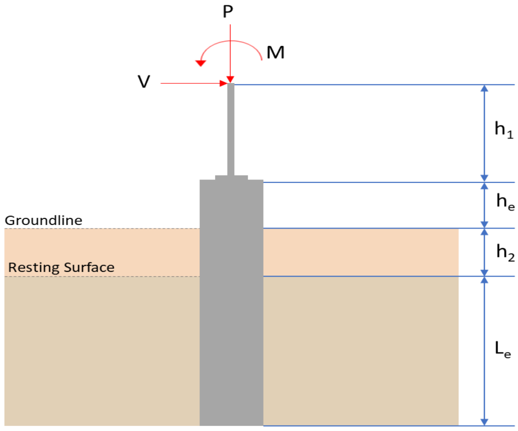
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 8\ \mathrm{ft}$ - 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)	9.155	13.511
V_x (kip)	-4.177	-6.968
V_z (kip)	0.017	0.028
M_x (kipft)	0.061	0.099
M_z (kipft)	54.073	91.680

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.177\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.66513\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(54.073\text{ kipft}) + ((-4.177\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 8.6104\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.3423\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.017\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.002707\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.061\text{ kipft}) + ((0.017\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.0097134\text{ kipft/ft}$$

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:
$L_{e,z} = 0.97814\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3423\text{ ft}), (0.97814\text{ ft})]$$

$$L_{e,req} = 7.342\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 8\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.342\text{ ft})}{(8\text{ ft})}$$

$$Ratio = 0.91775$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(9.155 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.57219 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.57219 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.28609$$

Status: **PASS**
Ratio: **0.290**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66513 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.6104 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.6104 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.66513 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (8.6104 \text{ kipft/ft})) + (4 \times (-0.66513 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5279 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.6104 \text{ kipft/ft})) + (3 \times (-0.66513 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (8.6104 \text{ kipft/ft})) + (2 \times (-0.66513 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.26344 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.6104 \text{ kipft/ft})) + ((-0.66513 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 1.1156 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5279 \text{ ft})}{2}$$

$$p_a = 0.41459 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.26344\ \mathrm{kip/ft^2}\right)}{\left(0.41459\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.63542$$	Status: **PASS** Ratio: **0.640**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$ $$p_s = 1.2\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1156\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92966$$	Status: **PASS** Ratio: **0.930**
	Considering z-direction: $H_o = 0.002707\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.0097134\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.0097134\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.0097134\ \mathrm{kipft/ft})) + (4 \times (0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$ $$a = 5.7319\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.0097134\ \mathrm{kipft/ft})) + (3 \times (0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.0097134\ \mathrm{kipft/ft})) + (2 \times (0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$ $$p = 0.0017434\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.0097134\ \mathrm{kipft/ft})) + ((0.002707\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$ $$s = 0.0038515\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7319\ \mathrm{ft})}{2}$$ $$p_a = 0.42989\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0017434\ \mathrm{kip/ft^2}\right)}{\left(0.42989\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.0040555$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

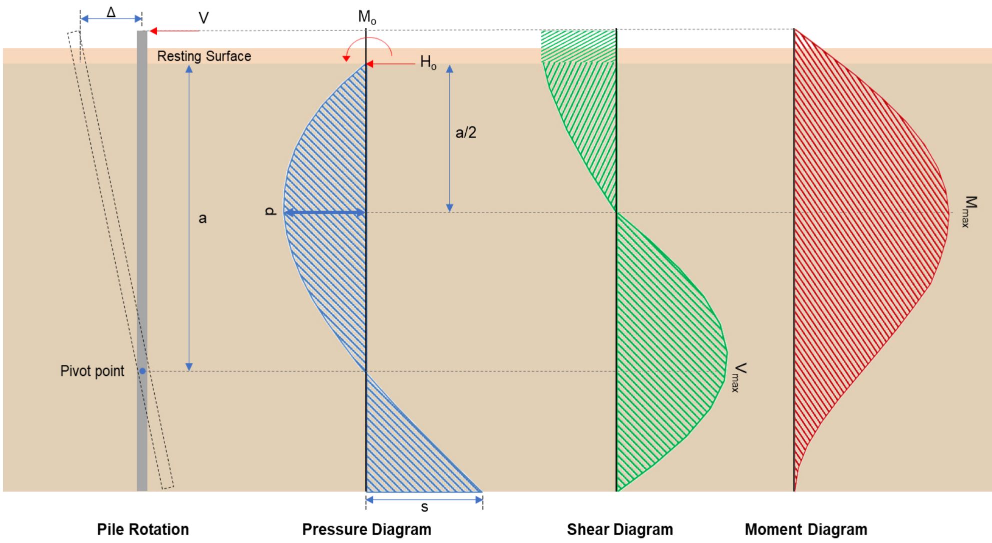
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0038515\ \mathrm{kip/ft^2})}{(1.2\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0032096$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.968\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1096\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(91.68\ \mathrm{kipft}) + ((-6.968\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.599\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.599\ \mathrm{kipft/ft})}{(-1.1096\ \mathrm{kip/ft})}$$

$$E = 13.157\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.599\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.1096\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (14.599\ \mathrm{kipft/ft})) + (4 \times (-1.1096\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5256\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1096\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.843\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1096\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (13.157\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5256\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 60.151\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.028\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0044586\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.099\ \mathrm{kipft}) + ((0.028\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.015764\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015764\ \mathrm{kipft/ft})}{(0.0044586\ \mathrm{kip/ft})}$$

$$E = 3.5357\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015764\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.0044586\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.015764\ \mathrm{kipft/ft})) + (4 \times (0.0044586\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7342\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0044586\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5357\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7342\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5357\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7342\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.025853\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0044586\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(3.5357\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.7342\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.5357\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7342\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5357\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7342\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.090705\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.511\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.147\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.147\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.511\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0050505$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.511 \text{ kip} \rightarrow 13511 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13511 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.29 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.29 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.29 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.29 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.27 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.843 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(15.843 \text{ kip})}{(111.27 \text{ kip})}$$ $$Ratio = 0.14239$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.025853 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.025853 \text{ kip})}{(111.27 \text{ kip})}$$ $$Ratio = 0.00023235$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 60.151 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(60.151 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.24099$$	Status: **PASS** Ratio: **0.240**
	Considering z-direction: $M_{max} = 0.090705 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.090705\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0003634$$		Status: **PASS** Ratio: **0.000**