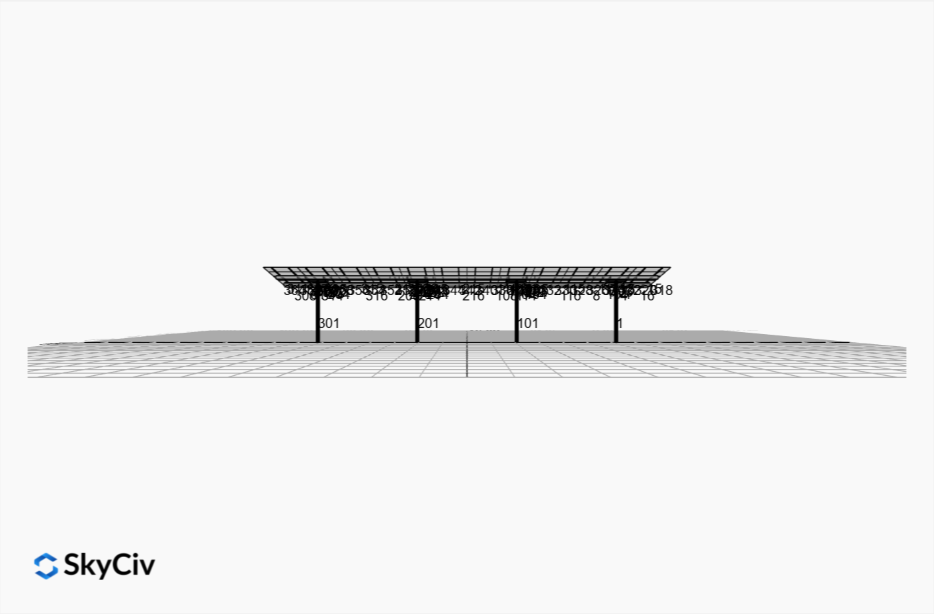
Project Details

Project Name: MTSOLAR_8LC7LFHKD82H
Date: Tue Jan 07 2025
Location: 821 W Hwy 50, O'Fallon, IL 62269, USA
Number of Modules: 60
Unique ID: 4P-22.5-8TOP-XD-57-L-5Hx12W-B011
Number of Poles: 4
Dealer: ______________________________
Date Sold: ______________________________



Array Dimensions N/S	21.71 ft
Array Dimensions E/W	86.60 ft
Winter Tilt Angle	10
Front Edge Clearance	12 ft

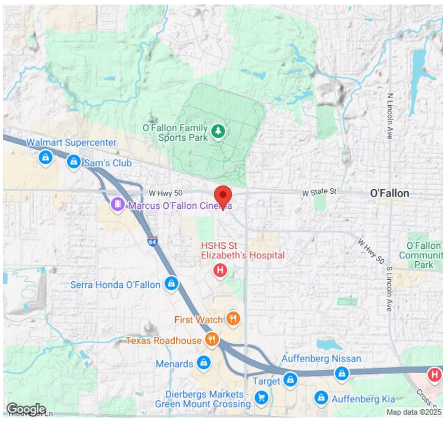
MT Solar Bill of Materials (4P-22.5-8TOP-XD-57-L-5Hx12W-B011)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-57	57IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	12
MTS-CLAMP-ANGLE-4PK	Angle Clamp	12

Rail Bill of Materials

Part	Qty
Rails (258in)	24
Rail Attachment	96
Module Mid Clamp	96
Module End Clamp	48
Ground Lug	12

Site Details:



Site Address: 821 W Hwy 50, O'Fallon, IL 62269, USA

Array Specification

Duty Classification:	XD
Module Width:	51.60 in
Module Length:	85.60in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Winter Tilt Angle:	10
Front Edge Clearance:	12
Total Array Height at Tilt:	15.77 ft
Total Frame Length:	84.50 ft
Frame Weight:	6173 lbs
Array Dimensions N/S:	21.71 ft
Array Dimensions E/W:	86.60 ft
Rail Length:	260.50 in
Rail Spacing:	3.61 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	13.88 ft
Number of Poles:	4
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.75 ft Pile 2: 9.00 ft Pile 3: 9.00 ft Pile 4: 8.75 ft
Foundation Volume:	9.294 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	821 W Hwy 50, O'Fallon, IL 62269, USA
Wind Speed:	101 mph

Snow Load:	20 psf

Design Disclaimer

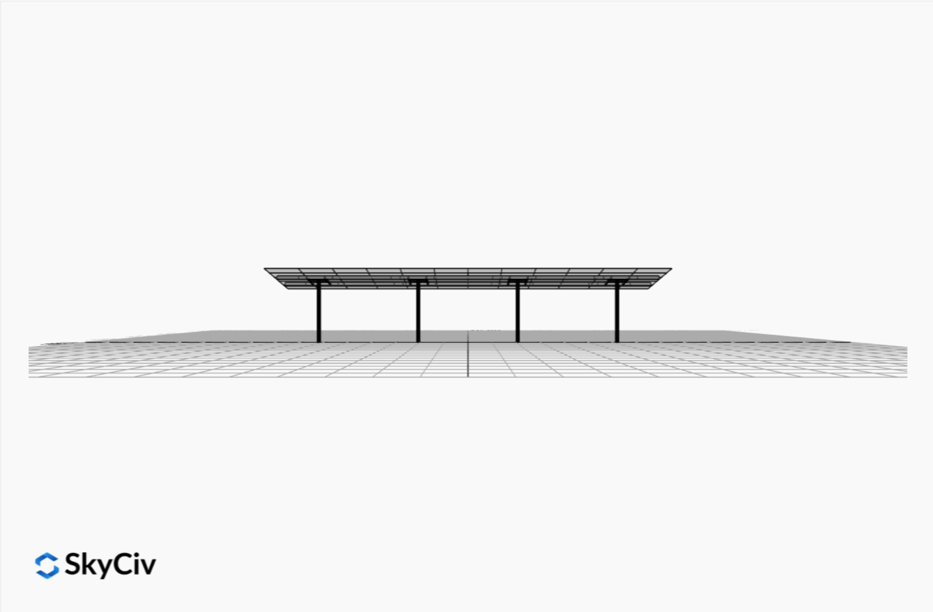
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

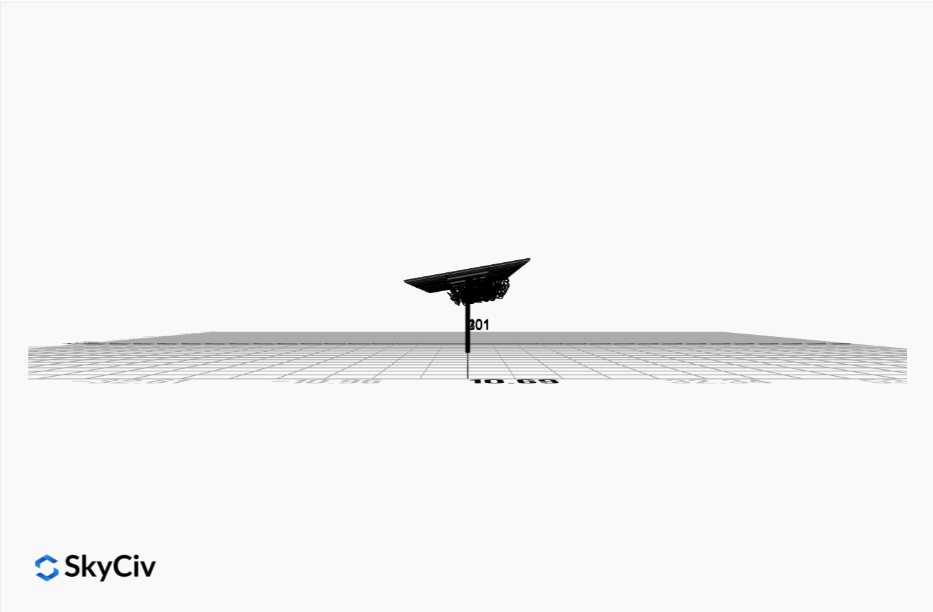
AutoDesigner Input

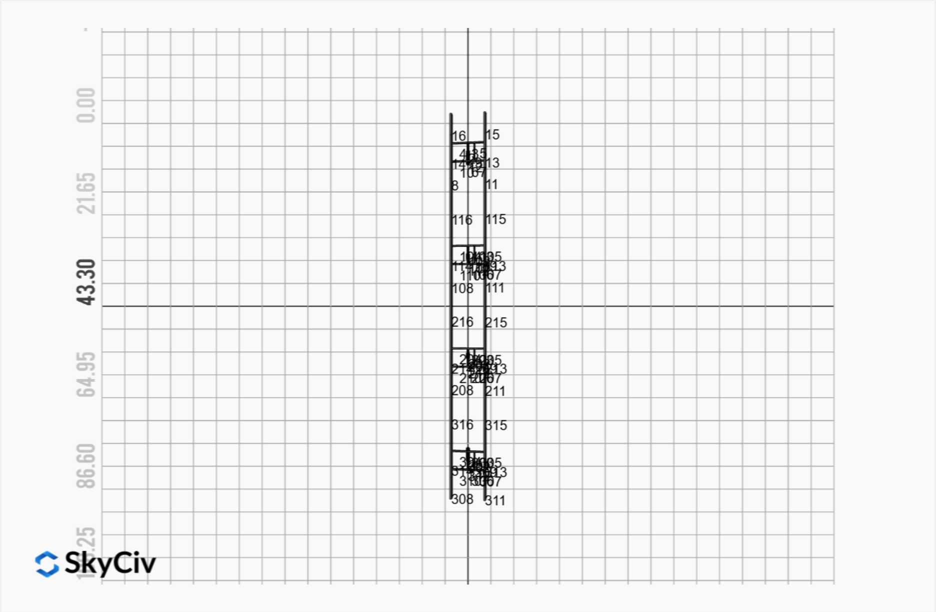

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"jm","designer_email":"jasonmitchell@gridsolarllc.com","designer_phone":"","project_id":"MTSOLAR_8LC7LFHKD82H","site_address":"821 W Hwy 50, O'Fallon, IL 62269, USA","module_width":51.6,"module_length":85.6,"number_rows":"5","number_columns":12,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":10,"ground_clearance":12,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false}
```

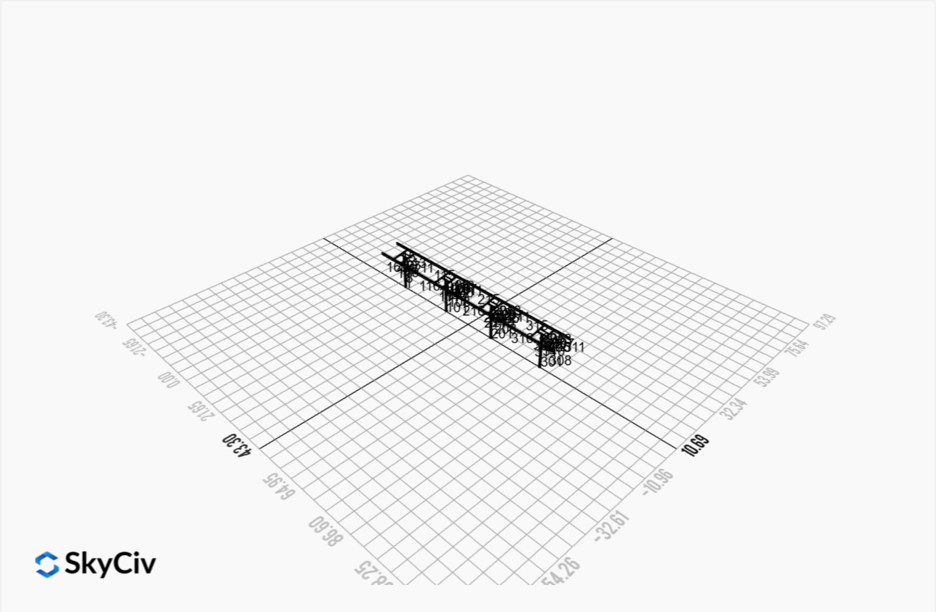

Design Notes:

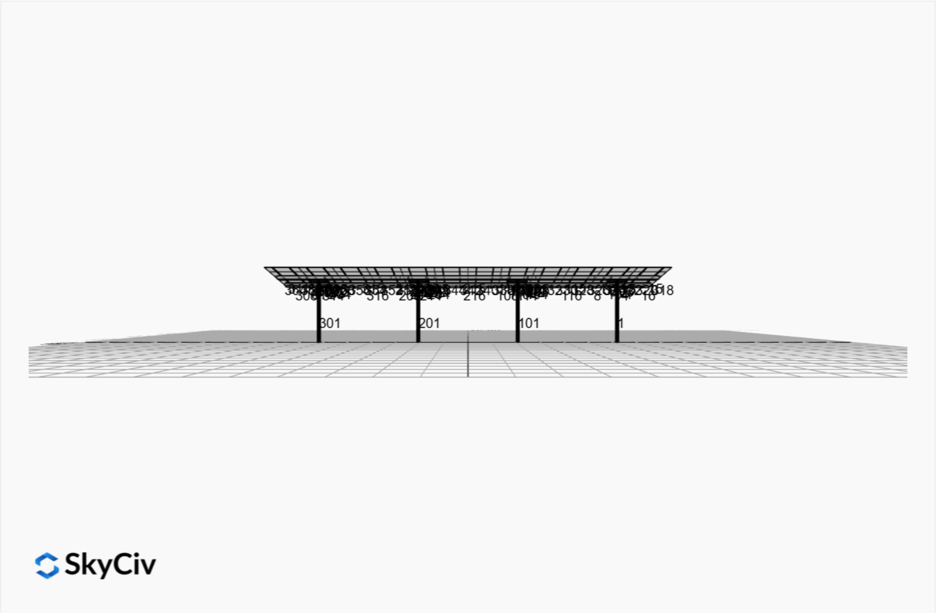
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



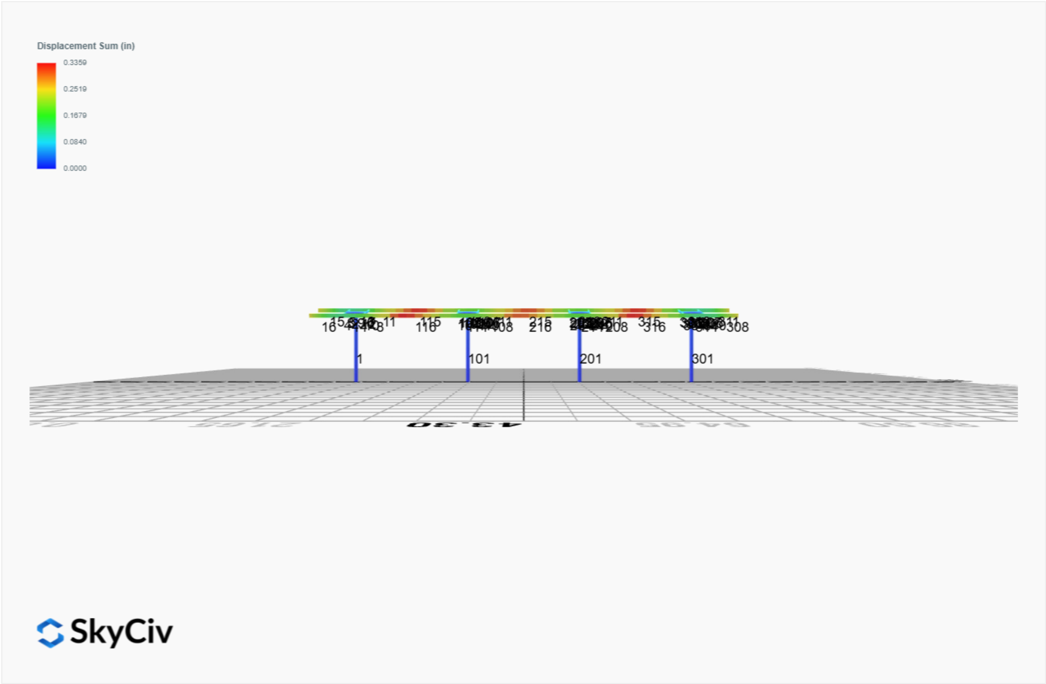


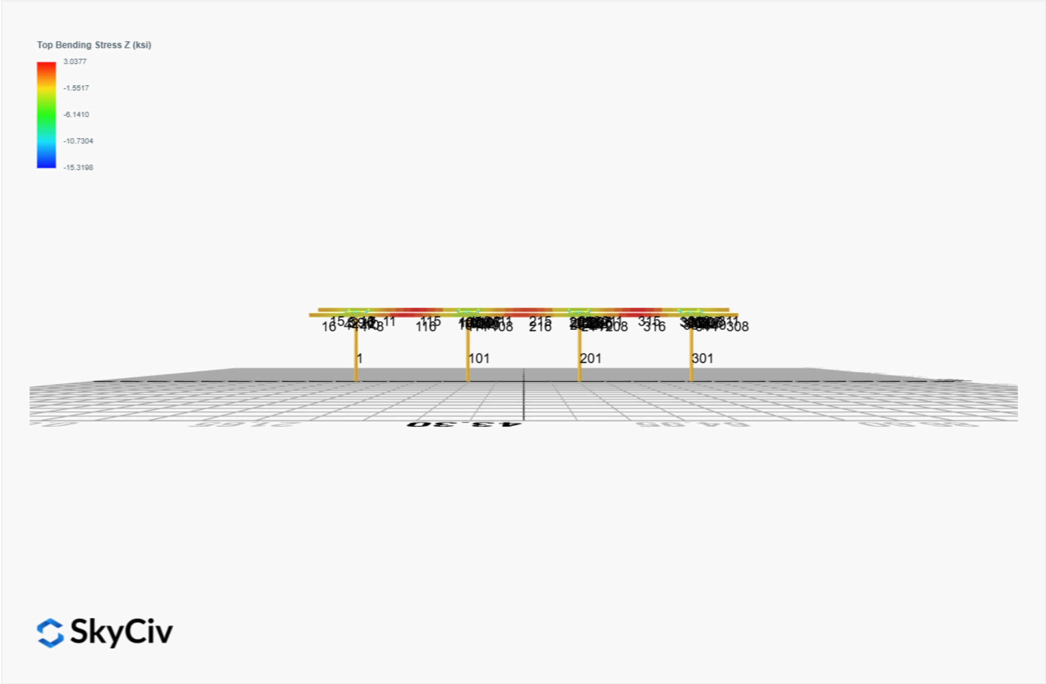

SkyCiv

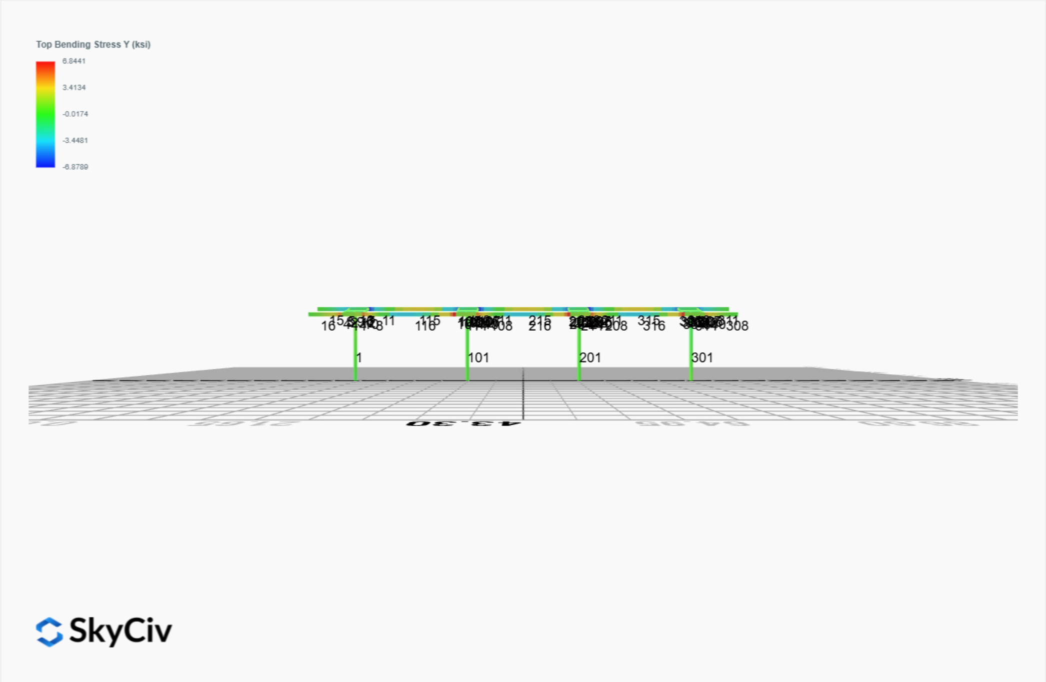

SkyCiv

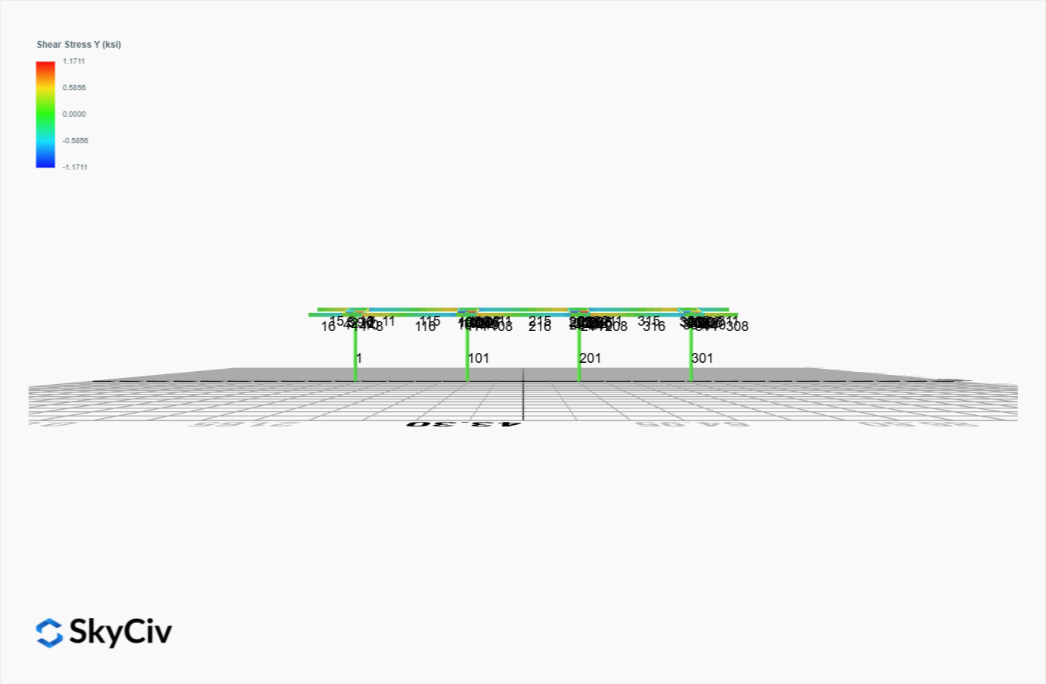

SkyCiv

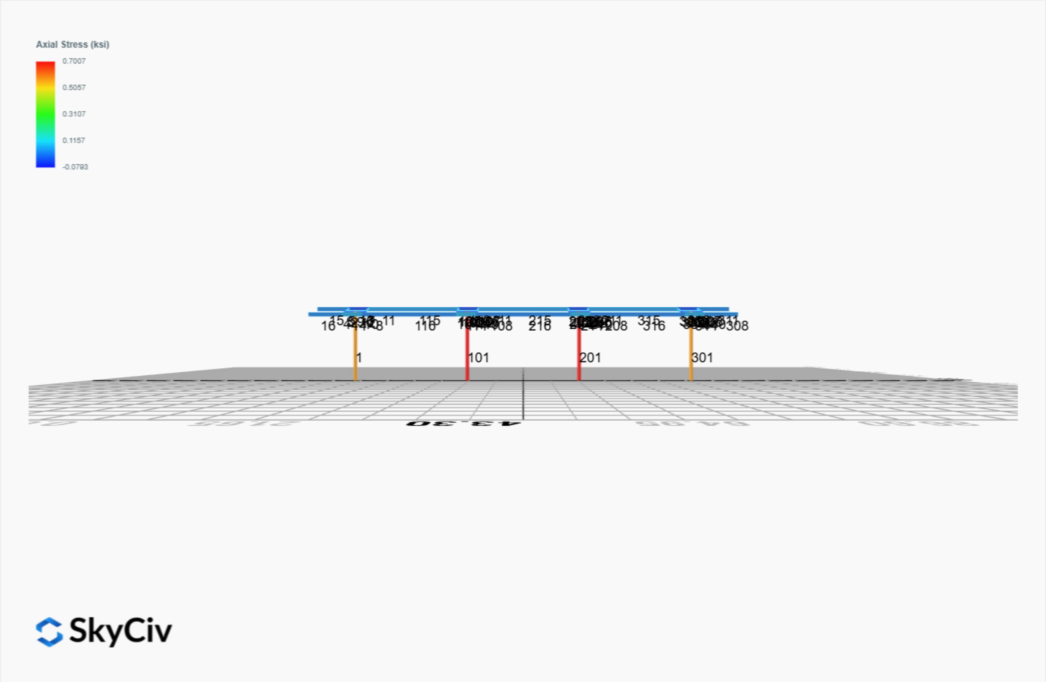
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
6.8441
3.4134
-0.0174
-3.4481
-6.8789
1
101
201
301
SkyCiv


Shear Stress Y (ksi)
1.1711
0.5856
0.0000
-0.5856
-1.1711
1
101
201
301
SkyCiv


Axial Stress (ksi)
0.7007
0.5057
0.3107
0.1157
-0.0793
1
101
201
301
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	0.0047	3.0380	0.0318	0.1385	-0.0026	-0.0278
ULS: 2. D + L	0.0047	3.0380	0.0318	0.1385	-0.0026	-0.0278
ULS: 3. D + (S or Lr or R)	0.0147	8.0785	0.0998	0.4351	-0.0085	-0.1503
ULS: 3. D + (S or Lr or R)	0.0047	3.0380	0.0318	0.1385	-0.0026	-0.0278
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0122	6.8184	0.0828	0.3610	-0.0071	-0.1197
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0047	3.0380	0.0318	0.1385	-0.0026	-0.0278
ULS: 5b. D + 0.7E	0.0047	3.0380	0.0318	0.1385	-0.0026	-0.0278
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0122	6.8184	0.0828	0.3610	-0.0071	-0.1197
ULS: 8. 0.6D + 0.7E	0.0028	1.8228	0.0191	0.0831	-0.0016	-0.0167
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.9224	8.2029	0.1107	0.4789	-0.0724	17.5451
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.9224	8.2029	0.1107	0.4789	-0.0724	17.5451
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6464	-0.5802	-0.0181	-0.0758	0.0370	-5.7611
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.5805	-0.1194	-0.0222	-0.0927	0.0506	-19.6331
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6831	10.6921	0.1420	0.6163	-0.0594	13.0600
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6831	10.6921	0.1420	0.6163	-0.0594	13.0600
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4935	4.1048	0.0453	0.2003	0.0227	-4.4196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4441	4.4503	0.0423	0.1876	0.0329	-14.8236
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6906	6.9117	0.0910	0.3938	-0.0550	13.1518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6906	6.9117	0.0910	0.3938	-0.0550	13.1518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4860	0.3244	-0.0056	-0.0222	0.0271	-4.3278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4366	0.6699	-0.0087	-0.0349	0.0373	-14.7318
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.9242	6.9878	0.0980	0.4235	-0.0714	17.5562
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.9242	6.9878	0.0980	0.4235	-0.0714	17.5562
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6446	-1.7954	-0.0308	-0.1312	0.0380	-5.7500
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5787	-1.3346	-0.0349	-0.1481	0.0517	-19.6219

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	16.0150
Shear X	-1.5451
Shear Z	0.2141
Moment X	0.9345
Moment Y (Twist)	0.1245
Moment Z	33.9787

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6921
Shear X	-0.9242
Shear Z	0.1420
Moment X	0.6163
Moment Y (Twist)	0.0724
Moment Z	19.6331

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	-0.0047	3.4348	-0.0039	-0.0169	0.0024	0.0951
ULS: 2. D + L	-0.0047	3.4348	-0.0039	-0.0169	0.0024	0.0951
ULS: 3. D + (S or Lr or R)	-0.0147	9.3199	-0.0121	-0.0532	0.0076	0.2397
ULS: 3. D + (S or Lr or R)	-0.0047	3.4348	-0.0039	-0.0169	0.0024	0.0951
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0122	7.8486	-0.0101	-0.0442	0.0063	0.2036

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0047	3.4348	-0.0039	-0.0169	0.0024	0.0951
ULS: 5b. D + 0.7E	-0.0047	3.4348	-0.0039	-0.0169	0.0024	0.0951
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0122	7.8486	-0.0101	-0.0442	0.0063	0.2036
ULS: 8. 0.6D + 0.7E	-0.0028	2.0609	-0.0023	-0.0102	0.0015	0.0570
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.0498	9.4545	-0.0071	-0.0322	-0.0059	19.9301
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.0498	9.4545	-0.0071	-0.0322	-0.0059	19.9301
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.7366	-0.7909	0.0014	0.0063	0.0011	-6.4792
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.6232	-0.2349	-0.0052	-0.0216	0.0158	-21.6519
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7960	12.3634	-0.0125	-0.0556	0.0001	15.0799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7960	12.3634	-0.0125	-0.0556	0.0001	15.0799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5438	4.6793	-0.0061	-0.0268	0.0053	-4.7271
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4588	5.0963	-0.0111	-0.0477	0.0164	-16.1067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7885	7.9496	-0.0063	-0.0284	-0.0038	14.9714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7885	7.9496	-0.0063	-0.0284	-0.0038	14.9714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5513	0.2655	0.0001	0.0005	0.0014	-4.8356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4663	0.6825	-0.0049	-0.0204	0.0125	-16.2152
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.0479	8.0806	-0.0056	-0.0254	-0.0069	19.8921
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.0479	8.0806	-0.0056	-0.0254	-0.0069	19.8921
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.7385	-2.1648	0.0030	0.0131	0.0001	-6.5172
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.6251	-1.6088	-0.0037	-0.0148	0.0148	-21.6900

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.5539
Shear X	-1.7505
Shear Z	-0.0202
Moment X	-0.0899
Moment Y (Twist)	0.0296
Moment Z	37.5106

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	12.3634
Shear X	-1.0498
Shear Z	-0.0125
Moment X	-0.0556
Moment Y (Twist)	0.0164
Moment Z	21.6900

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	-0.0047	3.4348	0.0039	0.0169	-0.0024	0.0951
ULS: 2. D + L	-0.0047	3.4348	0.0039	0.0169	-0.0024	0.0951
ULS: 3. D + (S or Lr or R)	-0.0147	9.3199	0.0121	0.0532	-0.0076	0.2397
ULS: 3. D + (S or Lr or R)	-0.0047	3.4348	0.0039	0.0169	-0.0024	0.0951
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0122	7.8486	0.0101	0.0442	-0.0063	0.2036
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0047	3.4348	0.0039	0.0169	-0.0024	0.0951
ULS: 5b. D + 0.7E	-0.0047	3.4348	0.0039	0.0169	-0.0024	0.0951
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0122	7.8486	0.0101	0.0442	-0.0063	0.2036
ULS: 8. 0.6D + 0.7E	-0.0028	2.0609	0.0023	0.0102	-0.0015	0.0570
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.0498	9.4545	0.0071	0.0322	0.0059	19.9301
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.0498	9.4545	0.0071	0.0322	0.0059	19.9301
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.7366	-0.7909	-0.0014	-0.0063	-0.0011	-6.4792
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.6232	-0.2349	0.0052	0.0216	-0.0158	-21.6519

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7960	12.3634	0.0125	0.0556	-0.0000	15.0799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7960	12.3634	0.0125	0.0556	-0.0000	15.0799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5438	4.6793	0.0061	0.0268	-0.0053	-4.7271
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4588	5.0963	0.0111	0.0477	-0.0163	-16.1067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7885	7.9496	0.0063	0.0284	0.0038	14.9714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7885	7.9496	0.0063	0.0284	0.0038	14.9714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.5513	0.2655	-0.0001	-0.0005	-0.0014	-4.8356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4663	0.6825	0.0049	0.0204	-0.0124	-16.2152
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.0479	8.0806	0.0056	0.0254	0.0069	19.8921
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.0479	8.0806	0.0056	0.0254	0.0069	19.8921
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.7385	-2.1648	-0.0030	-0.0131	-0.0001	-6.5172
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.6251	-1.6088	0.0037	0.0148	-0.0148	-21.6900

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.5539
Shear X	-1.7505
Shear Z	0.0202
Moment X	0.0899
Moment Y (Twist)	0.0296
Moment Z	37.5106

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	12.3634
Shear X	-1.0498
Shear Z	0.0125
Moment X	0.0556
Moment Y (Twist)	0.0163
Moment Z	21.6900

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	0.0047	3.0380	-0.0318	-0.1385	0.0027	-0.0278
ULS: 2. D + L	0.0047	3.0380	-0.0318	-0.1385	0.0027	-0.0278
ULS: 3. D + (S or Lr or R)	0.0147	8.0785	-0.0998	-0.4352	0.0086	-0.1502
ULS: 3. D + (S or Lr or R)	0.0047	3.0380	-0.0318	-0.1385	0.0027	-0.0278
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0122	6.8184	-0.0828	-0.3610	0.0071	-0.1196
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0047	3.0380	-0.0318	-0.1385	0.0027	-0.0278
ULS: 5b. D + 0.7E	0.0047	3.0380	-0.0318	-0.1385	0.0027	-0.0278
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0122	6.8184	-0.0828	-0.3610	0.0071	-0.1196
ULS: 8. 0.6D + 0.7E	0.0028	1.8228	-0.0191	-0.0831	0.0016	-0.0167
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.9224	8.2029	-0.1107	-0.4789	0.0724	17.5451
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.9224	8.2029	-0.1107	-0.4789	0.0724	17.5451
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.6464	-0.5802	0.0181	0.0758	-0.0370	-5.7611
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.5805	-0.1194	0.0222	0.0927	-0.0506	-19.6331
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6831	10.6921	-0.1420	-0.6163	0.0594	13.0601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6831	10.6921	-0.1420	-0.6163	0.0594	13.0601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4935	4.1048	-0.0453	-0.2003	-0.0226	-4.4196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4441	4.4503	-0.0423	-0.1876	-0.0329	-14.8235
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6906	6.9117	-0.0910	-0.3938	0.0550	13.1518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6906	6.9117	-0.0910	-0.3938	0.0550	13.1518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4860	0.3244	0.0056	0.0222	-0.0271	-4.3278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.4366	0.6699	0.0087	0.0349	-0.0373	-14.7318

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.9242	6.9878	-0.0980	-0.4235	0.0714	17.5562
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.9242	6.9878	-0.0980	-0.4235	0.0714	17.5562
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6446	-1.7954	0.0308	0.1312	-0.0380	-5.7500
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.5787	-1.3346	0.0349	0.1481	-0.0517	-19.6219

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	16.0150
Shear X	-1.5451
Shear Z	-0.2141
Moment X	-0.9345
Moment Y (Twist)	0.1247
Moment Z	33.9790

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6921
Shear X	-0.9242
Shear Z	-0.1420
Moment X	-0.6163
Moment Y (Twist)	0.0724
Moment Z	19.6331

Project Details

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

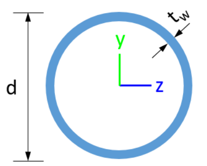
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

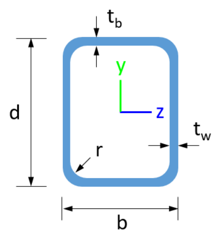
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

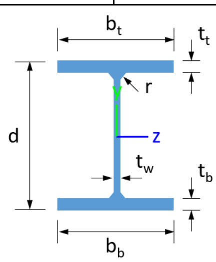
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
9	8in Pipe Sch 40	8.63	0.32					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	29.16	29.16	13.88	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.16,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.68	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.72,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.22,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.72,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.10,2.14,2.08,2.08,2.09,2.32,2.08,2.08,2.08,2.10,2.08,2.08,2.10,2.13,2.08,2.08,2.09,2.27	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.68	300	200	1
11	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.10,2.14,2.28,2.10,2.10,2.08,2.14,2.10,2.10,2.09,2.01,2.10,2.10,2.11,2.35,2.10,2.10,2.08,2.13	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.25,1.10,1.09,1.09,1.07,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.13,1.10,1.09,1.09,1.08,1.09	300	200	1
14	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.10,1.11,1.08,1.08,1.10,1.21,1.09,1.09,1.09,1.09,1.08,1.08,1.11,1.11,1.08,1.08,1.09,1.33	300	200	1
15	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	29.16	29.16	13.88	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
104	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.68,1.67,1.67,1.66,1.68	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.26,2.25,2.26,2.25,2.25,2.26,2.24,2.24,2.26,2.34,2.24,2.24,2.26,2.13,2.25,2.25,2.25,2.27,2.24,2.24,2.26,2.34,2.23,2.23,2.26,2.10	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.68,1.67,1.67,1.66,1.68	300	200	1
111	20	1.33	1.33	2.05	2.26,2.26,2.26,2.26,2.26,2.26,2.29,2.29,2.23,2.14,2.29,2.29,2.26,2.36,2.27,2.27,2.26,2.17,2.29,2.29,2.24,2.13,2.30,2.30,2.26,2.35	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.25,1.11,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.03,1.03,1.03,1.10,1.13,1.03,1.03,1.03,1.05	300	200	1
114	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.08,1.03,1.03,1.03,1.26,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.07,1.03,1.03,1.03,1.45	300	200	1
115	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.17,1.13,1.16,1.16,1.17,1.15,1.16,1.16,1.17,1.19,1.16,1.16,1.17,1.13,1.16,1.16,1.17,1.15	300	200	1
116	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.17,1.15,1.18,1.18,1.17,1.13,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.15,1.18,1.18,1.17,1.13	300	200	1
201	9	29.16	29.16	13.88	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
204	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.68,1.67,1.67,1.66,1.68	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.30,2.30,2.30,2.30,2.30,2.30,2.28,2.28,2.32,2.14,2.27,2.27,2.31,2.09,2.29,2.29,2.30,2.33,2.28,2.28,2.32,2.14,2.27,2.27,2.31,1.96	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.68,1.67,1.67,1.66,1.68	300	200	1
211	20	1.33	1.33	2.05	2.31,2.31,2.31,2.31,2.31,2.31,2.35,2.35,2.27,2.10,2.36,2.36,2.31,2.13,2.33,2.33,2.30,2.23,2.35,2.35,2.29,2.09,2.36,2.36,2.31,2.13	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.25,1.11,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.03,1.03,1.03,1.10,1.13,1.03,1.03,1.03,1.05	300	200	1
214	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.08,1.03,1.03,1.03,1.26,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.07,1.03,1.03,1.03,1.45	300	200	1
215	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.15,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.19,1.17,1.17,1.18,1.15,1.17,1.17,1.17,1.16	300	200	1
216	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.17,1.16,1.18,1.18,1.17,1.15,1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.16,1.18,1.18,1.17,1.14	300	200	1
301	9	29.16	29.16	13.88	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.22,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18	300	200	1
304	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.68	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.72,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.17,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.16,1.18,1.18,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.72,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.65,1.67,1.67,1.66,1.66	300	200	1
308	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.68	300	200	1
311	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.25,1.10,1.09,1.09,1.07,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.13,1.10,1.09,1.09,1.08,1.09	300	200	1
314	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.10,1.11,1.08,1.08,1.10,1.21,1.09,1.09,1.09,1.09,1.08,1.08,1.11,1.11,1.08,1.08,1.09,1.33	300	200	1

315	20	8.42	8.42	12.95	1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.14,1.14,1.16,1.14,1.14,1.13,1.15,1.13,1.13,1.13,1.13,1.14,1.14,1.14,1.16,1.14,1.14,1.13,1.15	300	200	1
316	20	8.42	8.42	12.95	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.15,1.13,1.13,1.13,1.17,1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.15,1.13,1.13,1.13,1.18	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	133.76	83.29	83.29	113.39	113.39
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	32.80	6.46	56.26	44.91
14	159.30	97.43	33.10	6.46	56.26	44.91
15	159.30	34.37	46.90	6.46	56.26	44.91
16	159.30	34.37	46.90	6.46	56.26	44.91
101	377.97	133.76	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.34	6.46	56.26	44.91
114	159.30	97.43	31.46	6.46	56.26	44.91
115	159.30	48.27	15.04	6.46	56.26	44.91
116	159.30	48.27	15.01	6.46	56.26	44.91
201	377.97	133.76	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.33	6.46	56.26	44.91
214	159.30	97.43	31.46	6.46	56.26	44.91
215	159.30	48.27	15.24	6.46	56.26	44.91
216	159.30	48.27	15.14	6.46	56.26	44.91
301	377.97	133.76	83.29	83.29	113.39	113.39
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	34.37	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	34.37	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	32.80	6.46	56.26	44.91
314	159.30	97.43	33.10	6.46	56.26	44.91
315	159.30	48.27	15.03	6.46	56.26	44.91
316	159.30	48.27	15.05	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.120	0.408	0.024	0.014	0.002	0.429	#13	0.596	Not Required	Pass
2	0.002	0.461	0.057	0.098	0.010	0.506	#21	0.036	Not Required	Pass
3	0.003	0.713	0.016	0.071	0.004	0.719	#21	0.046	Not Required	Pass
4	0.003	0.635	0.062	0.064	0.014	0.679	#21	0.082	Not Required	Pass
5	0.003	0.442	0.058	0.071	0.015	0.455	#21	0.076	Not Required	Pass
6	0.004	0.789	0.029	0.079	0.004	0.819	#21	0.046	Not Required	Pass
7	0.004	0.489	0.084	0.078	0.022	0.512	#21	0.076	Not Required	Pass
8	0.001	0.066	0.105	0.047	0.008	0.134	#24	0.102	Not Required	Pass
9	0.008	0.088	0.030	0.002	0.001	0.121	#21	0.206	Not Required	Pass
10	0.004	0.698	0.077	0.070	0.016	0.735	#21	0.082	Not Required	Pass
11	0.001	0.070	0.108	0.053	0.008	0.132	#21	0.102	Not Required	Pass
12	0.001	0.536	0.062	0.109	0.011	0.583	#21	0.054	Not Required	Pass
13	0.003	0.287	0.220	0.066	0.010	0.433	#21	0.306	Not Required	Pass
14	0.004	0.259	0.217	0.058	0.010	0.395	#21	0.204	Not Required	Pass
15	0.000	0.098	0.085	0.035	0.005	0.183	#21	Not Required	Not Required	Pass
16	0.000	0.088	0.085	0.031	0.005	0.173	#21	Not Required	Not Required	Pass
101	0.139	0.450	0.002	0.015	0.000	0.479	#13	0.596	Not Required	Pass
102	0.002	0.584	0.069	0.121	0.011	0.638	#21	0.036	Not Required	Pass
103	0.004	0.874	0.020	0.087	0.000	0.895	#21	0.046	Not Required	Pass
104	0.004	0.785	0.080	0.078	0.017	0.835	#21	0.082	Not Required	Pass
105	0.004	0.542	0.084	0.087	0.022	0.565	#21	0.076	Not Required	Pass
106	0.004	0.870	0.019	0.087	0.002	0.888	#21	0.046	Not Required	Pass
107	0.004	0.540	0.079	0.086	0.021	0.562	#21	0.076	Not Required	Pass
108	0.001	0.073	0.097	0.049	0.008	0.170	#21	0.102	Not Required	Pass
109	0.009	0.089	0.022	0.001	0.000	0.115	#21	0.206	Not Required	Pass
110	0.004	0.775	0.076	0.078	0.016	0.825	#21	0.082	Not Required	Pass

111	0.002	0.076	0.099	0.055	0.008	0.176	#21	0.102	Not Required	Pass
112	0.002	0.577	0.069	0.120	0.012	0.631	#21	0.036	Not Required	Pass
113	0.003	0.328	0.222	0.069	0.010	0.521	#21	0.306	Not Required	Pass
114	0.005	0.311	0.221	0.062	0.010	0.499	#21	0.306	Not Required	Pass
115	0.004	0.575	0.113	0.056	0.008	0.689	#21	0.644	Not Required	Pass
116	0.002	0.509	0.114	0.051	0.008	0.624	#21	0.644	Not Required	Pass
201	0.139	0.450	0.002	0.015	0.000	0.479	#13	0.596	Not Required	Pass
202	0.002	0.577	0.069	0.120	0.012	0.631	#21	0.036	Not Required	Pass
203	0.004	0.870	0.019	0.087	0.002	0.888	#21	0.046	Not Required	Pass
204	0.004	0.775	0.076	0.078	0.016	0.825	#21	0.082	Not Required	Pass
205	0.004	0.540	0.079	0.086	0.021	0.562	#21	0.076	Not Required	Pass
206	0.004	0.874	0.020	0.087	0.000	0.895	#21	0.046	Not Required	Pass
207	0.004	0.542	0.084	0.087	0.022	0.565	#21	0.076	Not Required	Pass
208	0.001	0.068	0.108	0.051	0.008	0.176	#21	0.102	Not Required	Pass
209	0.009	0.089	0.022	0.001	0.000	0.115	#21	0.206	Not Required	Pass
210	0.004	0.785	0.080	0.078	0.017	0.835	#21	0.082	Not Required	Pass
211	0.001	0.069	0.110	0.056	0.008	0.180	#21	0.102	Not Required	Pass
212	0.002	0.584	0.069	0.121	0.011	0.638	#21	0.036	Not Required	Pass
213	0.003	0.328	0.222	0.069	0.010	0.522	#21	0.306	Not Required	Pass
214	0.005	0.311	0.221	0.062	0.010	0.499	#21	0.306	Not Required	Pass
215	0.004	0.508	0.113	0.055	0.008	0.620	#21	0.644	Not Required	Pass
216	0.003	0.436	0.113	0.049	0.008	0.549	#21	0.644	Not Required	Pass
301	0.120	0.408	0.024	0.014	0.002	0.429	#13	0.596	Not Required	Pass
302	0.001	0.536	0.062	0.109	0.011	0.583	#21	0.054	Not Required	Pass
303	0.004	0.789	0.029	0.079	0.004	0.819	#21	0.046	Not Required	Pass
304	0.004	0.698	0.077	0.070	0.016	0.735	#21	0.082	Not Required	Pass
305	0.004	0.489	0.084	0.078	0.022	0.512	#21	0.076	Not Required	Pass
306	0.003	0.713	0.016	0.071	0.004	0.719	#21	0.046	Not Required	Pass
307	0.003	0.442	0.058	0.071	0.015	0.455	#21	0.076	Not Required	Pass
308	0.000	0.088	0.085	0.031	0.005	0.173	#21	Not Required	Not Required	Pass
309	0.008	0.088	0.030	0.002	0.001	0.121	#21	0.206	Not Required	Pass
310	0.003	0.635	0.062	0.064	0.014	0.679	#21	0.082	Not Required	Pass
311	0.000	0.098	0.085	0.035	0.005	0.183	#21	Not Required	Not Required	Pass
312	0.002	0.461	0.057	0.098	0.010	0.506	#21	0.036	Not Required	Pass
313	0.003	0.287	0.220	0.066	0.010	0.433	#21	0.204	Not Required	Pass
314	0.004	0.259	0.217	0.058	0.010	0.395	#21	0.306	Not Required	Pass
315	0.004	0.584	0.113	0.053	0.008	0.697	#21	0.644	Not Required	Pass
316	0.002	0.522	0.113	0.047	0.008	0.634	#21	0.644	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

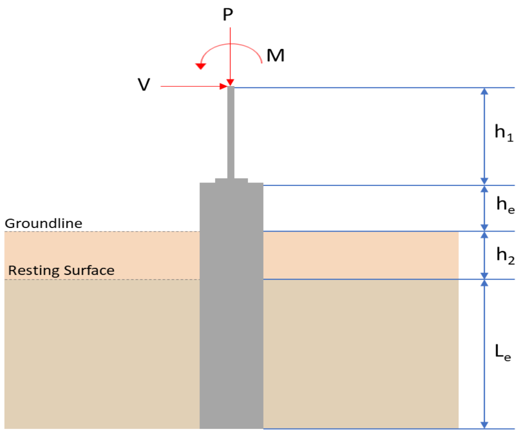
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 8.75 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.692	16.015
V_x (kip)	-0.924	-1.545
V_z (kip)	0.142	0.214
M_x (kipft)	0.616	0.934
M_z (kipft)	19.633	33.979

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.924 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.308 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(19.633\ \text{kipft}) + ((-0.924\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 6.5443\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.3407\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.142\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.047333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.616\ \text{kipft}) + ((0.142\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.20533\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.4542\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.3407\ \text{ft}), (3.4542\ \text{ft})]$$

$$L_{e,req} = 8.341\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.341\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.95326$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(10.692\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.5126\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.5126\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.7563$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.308\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5443\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5443\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (6.5443\ \mathrm{kipft/ft})) + (4 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 5.9904\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.5443\ \mathrm{kipft/ft})) + (3 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (6.5443\ \mathrm{kipft/ft})) + (2 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.3536\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (6.5443\ \mathrm{kipft/ft})) + ((-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.2795\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9904\ \mathrm{ft})}{2}$$

$$p_a = 0.44928\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.3536 \text{ kip/ft}^2\right)}{\left(0.44928 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.78705$$

Status: **PASS**
Ratio: **0.790**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

$$p_s = 1.3125 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2795 \text{ kip/ft}^2\right)}{\left(1.3125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.97484$$

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

Considering z-direction:

$H_o = 0.047333 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.20533 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20533 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (0.047333 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.20533 \text{ kipft/ft})) + (4 \times (0.047333 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.2515 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.20533 \text{ kipft/ft})) + (3 \times (0.047333 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (0.20533 \text{ kipft/ft})) + (2 \times (0.047333 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.045374 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.20533 \text{ kipft/ft})) + ((0.047333 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 0.10154 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.2515 \text{ ft})}{2}$$

$$p_a = 0.46886 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.045374 \text{ kip/ft}^2\right)}{\left(0.46886 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.096775$$

Status: **PASS**
Ratio: **0.100**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.75\ \text{ft})$$

$$p_s = 1.3125\ \text{kip/ft}^2$$

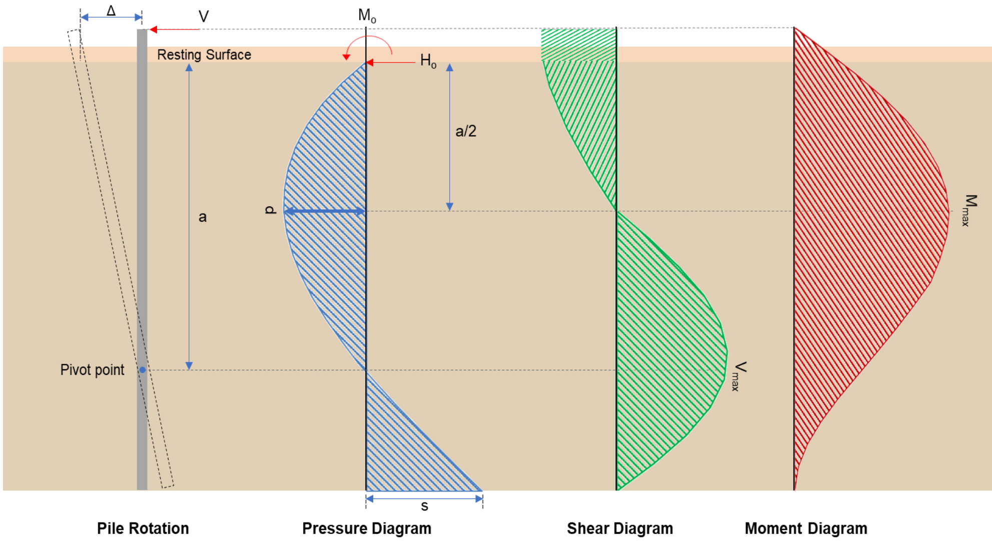
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.10154\ \text{kip/ft}^2\right)}{\left(1.3125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.077363$$

Status: **PASS**
Ratio: **0.080**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.545\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.515\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(33.979\ \text{kipft}) + ((-1.545\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.326\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.326\ \text{kipft/ft})}{(-0.515\ \text{kip/ft})}$$

$$E = 21.993\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.326\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.515\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (11.326\ \text{kipft/ft})) + (4 \times (-0.515\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 5.9862\ \text{ft}$$

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

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

$$V_{max} = ((-0.515\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(5.9862\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(5.9862\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.8946\ \text{kip}$$

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

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

$$M_{max} = ((-0.515\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(21.993\ \text{ft})}{(8.75\ \text{ft})} + \frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 33.306\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.214\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.071333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.934\ \text{kipft}) + ((0.214\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.31133\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.31133\ \text{kipft/ft})}{(0.071333\ \text{kip/ft})}$$

$$E = 4.3645\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31133\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (0.071333\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (0.31133\ \text{kipft/ft})) + (4 \times (0.071333\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.2504\ \text{ft}$$

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

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

$$V_{max} = ((0.071333\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.3645\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.2504\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.3645\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.2504\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33147\ \text{kip}$$

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

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

$$M_{max} = ((0.071333\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(4.3645\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.2504\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.3645\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.2504\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.3645\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.2504\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.2832\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.015\ \text{kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.873\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.873\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

$$(1.8322\ \text{in}^2)$$

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

$$Ratio = 0.99533$$

Status: PASS
Ratio: 1.000

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.015 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.012772$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.015\ \text{kip} \rightarrow 16015\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(16015\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 77.157\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (77.157\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 77.157\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((77.157\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.963\ \text{kip}$$

Considering x-direction:

$V_{max} = 7.8946\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(7.8946 \text{ kip})}{(74.963 \text{ kip})}$$ $$Ratio = 0.10531$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.33147 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.33147 \text{ kip})}{(74.963 \text{ kip})}$$ $$Ratio = 0.0044218$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi D^3}{32}$$ $$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$ $$S_m = 4580.4 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 33.306 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(33.306 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.53696$$	Status: **PASS** Ratio: **0.540**
	Considering z-direction: $M_{max} = 1.2832 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{...}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(1.2832\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.020687$$	Status: **PASS** Ratio: **0.020**

REFERENCES	CALCULATIONS	RESULTS

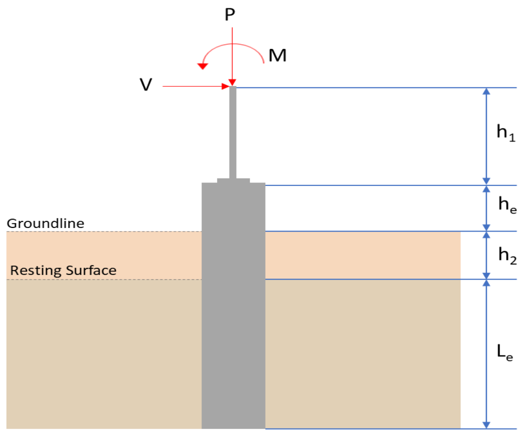
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round

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

$L = 8.75\ \mathrm{ft}$ - Total pile length

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

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

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.692	16.015
V_x (kip)	-0.924	-1.545
V_z (kip)	-0.142	-0.214
M_x (kipft)	-0.616	-0.934
M_z (kipft)	19.633	33.979

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.924\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.308\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(19.633\ \text{kipft}) + ((-0.924\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 6.5443\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.3407\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.142\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.047333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.616\ \text{kipft}) + ((-0.142\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.20533\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.4574\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.3407\ \text{ft}), (2.4574\ \text{ft})]$$

$$L_{e,req} = 8.341\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.341\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.95326$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(10.692\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.5126\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.5126\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.7563$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.308\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5443\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5443\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (6.5443\ \mathrm{kipft/ft})) + (4 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 5.9904\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.5443\ \mathrm{kipft/ft})) + (3 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (6.5443\ \mathrm{kipft/ft})) + (2 \times (-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.3536\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (6.5443\ \mathrm{kipft/ft})) + ((-0.308\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.2795\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9904\ \mathrm{ft})}{2}$$

$$p_a = 0.44928\ \mathrm{kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.3536\ \mathrm{kip/ft^2}\right)}{\left(0.44928\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.78705$$	Status: **PASS** Ratio: **0.790**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$ $$p_s = 1.3125\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.2795\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.97484$$	Status: **PASS** Ratio: **0.970**
	Considering z-direction: $H_o = -0.047333\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.20533\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.20533\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.047333\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.20533\ \mathrm{kipft/ft})) + (4 \times (-0.047333\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$ $$a = 6.2515\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (0.20533\ \mathrm{kipft/ft})) + (3 \times (-0.047333\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.20533\ \mathrm{kipft/ft})) + (2 \times (-0.047333\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$ $$p = -0.012853\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (0.20533\ \mathrm{kipft/ft})) + ((-0.047333\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$ $$s = -0.00043086\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2515\ \mathrm{ft})}{2}$$ $$p_a = 0.46886\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.012853\ \mathrm{kip/ft^2}\right)}{\left(0.46886\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = -0.027414$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.75\ \text{ft})$$

$$p_s = 1.3125\ \text{kip/ft}^2$$

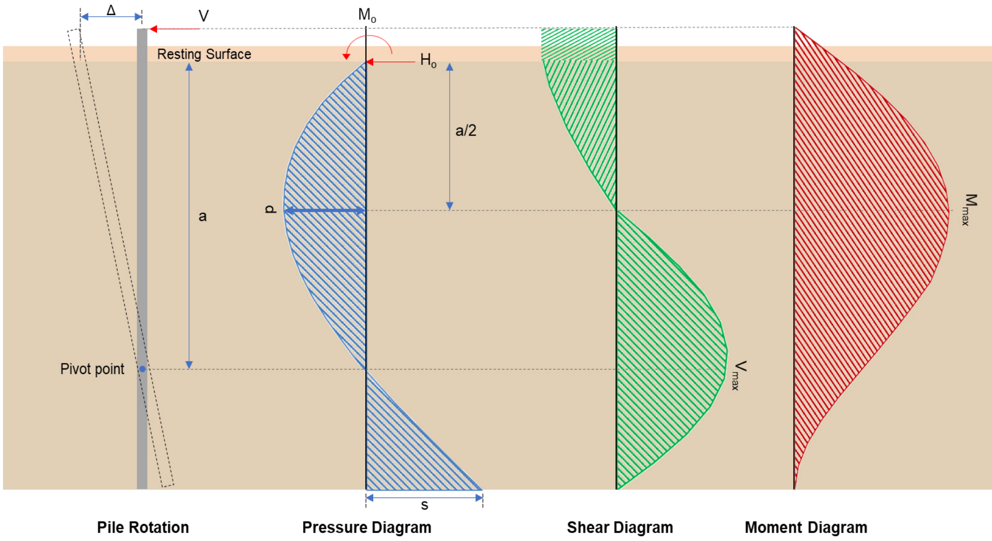
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00043086\ \text{kip/ft}^2\right)}{\left(1.3125\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.00032827$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.545\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.515\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(33.979\ \text{kipft}) + ((-1.545\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.326\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.326\ \text{kipft/ft})}{(-0.515\ \text{kip/ft})}$$

$$E = 21.993\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.326\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.515\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (11.326\ \text{kipft/ft})) + (4 \times (-0.515\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 5.9862\ \text{ft}$$

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

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

$$V_{max} = ((-0.515\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(5.9862\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(5.9862\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.8946\ \text{kip}$$

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

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

$$M_{max} = ((-0.515\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(21.993\ \text{ft})}{(8.75\ \text{ft})} + \frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.993\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(5.9862\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 33.306\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.214\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.071333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.934\ \text{kipft}) + ((-0.214\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.31133\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.31133\ \text{kipft/ft})}{(-0.071333\ \text{kip/ft})}$$

$$E = 4.3645\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.31133\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.071333\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (0.31133\ \text{kipft/ft})) + (4 \times (-0.071333\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.2504\ \text{ft}$$

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

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

$$V_{max} = ((-0.071333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.3645 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.2504 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.3645 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.2504 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33147 \text{ kip}$$

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

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

$$M_{max} = ((-0.071333 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(4.3645 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.2504 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (4.3645 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.2504 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.3645 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.2504 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.2832 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.015 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -36.873 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-36.873 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

$$\left(1.8322 \text{ in}^2\right)$$

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

$$Ratio = 0.99533$$

Status: PASS
Ratio: 1.000

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.015\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.012772$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.015 \text{ kip} \rightarrow 16015 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(16015 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.157 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (77.157 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 77.157 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((77.157 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.963 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.8946 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.8946 \text{ kip})}{(74.963 \text{ kip})}$$

$$Ratio = 0.10531$$

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

Considering z-direction:

$V_{max} = 0.33147 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33147 \text{ kip})}{(74.963 \text{ kip})}$$

$$Ratio = 0.0044218$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 33.306 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(33.306 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.53696$$

Status: **PASS**
Ratio: **0.540**

Considering z-direction:

$M_{max} = 1.2832 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(1.2832 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.020687$$	Status: **PASS** Ratio: **0.020**

REFERENCES	CALCULATIONS	RESULTS

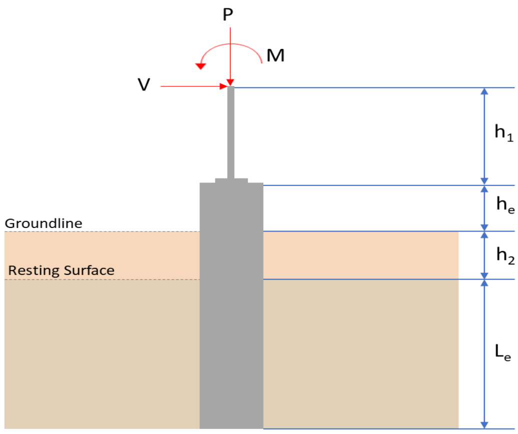
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 9\ \mathrm{ft}$ - 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)	12.363	18.554
V_x (kip)	-1.050	-1.750
V_z (kip)	-0.012	-0.020
M_x (kipft)	-0.056	-0.090
M_z (kipft)	21.690	37.511

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.05\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.35\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.69\text{ kipft}) + ((-1.05\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 7.23\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.5557\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056\text{ kipft}) + ((-0.012\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 0.018667\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.2344\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.5557\text{ ft}), (1.2344\text{ ft})]$$

$$L_{e,req} = 8.556\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 9\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.556\text{ ft})}{(9\text{ ft})}$$

$$Ratio = 0.95067$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(12.363 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.749 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.749 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.8745$$

Status: **PASS**
Ratio: **0.870**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 3$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.35 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.23 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.23 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (7.23 \text{ kipft/ft})) + (4 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.1688 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.23 \text{ kipft/ft})) + (3 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]^{\ 2}}{(9 \text{ ft})^2 \times [(3 \times (7.23 \text{ kipft/ft})) + (2 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.35822 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.23 \text{ kipft/ft})) + ((-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.316 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.1688 \text{ ft})}{2}$$

$$p_a = 0.46266 \text{ kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.35822\ \text{kip}/\text{ft}^2\right)}{\left(0.46266\ \text{kip}/\text{ft}^2\right)}$$ $$Ratio = 0.77427$$	Status: **PASS** Ratio: **0.770**	
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \text{psf}/\text{ft}) \times (9\ \text{ft})$$ $$p_s = 1.35\ \text{kip}/\text{ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.316\ \text{kip}/\text{ft}^2\right)}{\left(1.35\ \text{kip}/\text{ft}^2\right)}$$ $$Ratio = 0.97482$$	Status: **PASS** Ratio: **0.970**	

Considering z-direction:

$H_o = -0.004\ \text{kip}/\text{ft}$ - Lateral force per length of pile,
$M_o = 0.018667\ \text{kipft}/\text{ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.018667\ \text{kipft}/\text{ft}) \times (9\ \text{ft})) + \left(3 \times (-0.004\ \text{kip}/\text{ft}) \times (9\ \text{ft})^2\right)}{(6 \times (0.018667\ \text{kipft}/\text{ft})) + (4 \times (-0.004\ \text{kip}/\text{ft}) \times (9\ \text{ft}))}$$

$$a = 6.4219\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.018667\ \text{kipft}/\text{ft})) + (3 \times (-0.004\ \text{kip}/\text{ft}) \times (9\ \text{ft}))]^{\ 2}}{(9\ \text{ft})^2 \times [(3 \times (0.018667\ \text{kipft}/\text{ft})) + (2 \times (-0.004\ \text{kip}/\text{ft}) \times (9\ \text{ft}))]}$$

$$p = -0.0010099\ \text{kip}/\text{ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.018667\ \text{kipft}/\text{ft})) + ((-0.004\ \text{kip}/\text{ft}) \times (9\ \text{ft}))]}{(9\ \text{ft})^2}$$

$$s = 0.00015514\ \text{kip}/\text{ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf}/\text{ft}) \times \frac{(6.4219\ \text{ft})}{2}$$

$$p_a = 0.48164\ \text{kip}/\text{ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0010099\ \text{kip}/\text{ft}^2\right)}{\left(0.48164\ \text{kip}/\text{ft}^2\right)}$$

$$Ratio = -0.0020969$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (9\ \text{ft})$$

$$p_s = 1.35\ \text{kip/ft}^2$$

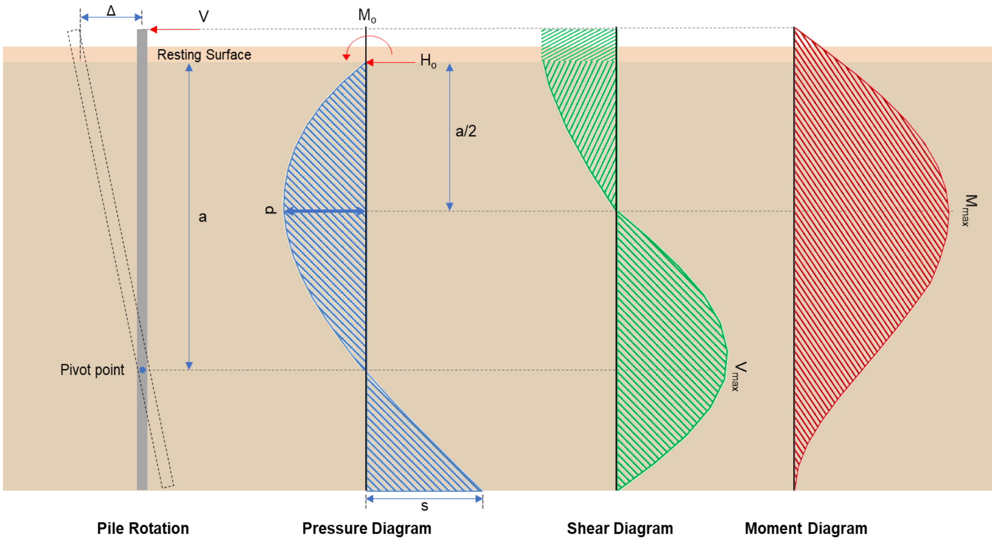
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00015514\ \text{kip/ft}^2)}{(1.35\ \text{kip/ft}^2)}$$

$$Ratio = 0.00011492$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.75\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.58333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.511\ \text{kipft}) + ((-1.75\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 12.504\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.504\ \text{kipft/ft})}{(-0.58333\ \text{kip/ft})}$$

$$E = 21.435\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.504\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (-0.58333\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (12.504\ \text{kipft/ft})) + (4 \times (-0.58333\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.164\ \text{ft}$$

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

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

$$V_{max} = ((-0.58333\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.435\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.164\ \text{ft})}{(9\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.435\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.164\ \text{ft})}{(9\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.5329\ \text{kip}$$

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

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

$$M_{max} = ((-0.58333\ \text{kip/ft}) \times (36\ \text{in}) \times (9\ \text{ft})) \times \left[\left(\frac{(21.435\ \text{ft})}{(9\ \text{ft})} + \frac{(6.164\ \text{ft})}{2 \times (9\ \text{ft})}\right) - \left[\left(\frac{4 \times (21.435\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.164\ \text{ft})}{2 \times (9\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.435\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.164\ \text{ft})}{2 \times (9\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 36.962\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.02\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.0066667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.09\ \text{kipft}) + ((-0.02\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.03\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.03\ \text{kipft/ft})}{(-0.0066667\ \text{kip/ft})}$$

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.03\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (-0.0066667\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (0.03\ \text{kipft/ft})) + (4 \times (-0.0066667\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.4286\ \text{ft}$$

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

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

$$V_{max} = ((-0.0066667\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.4286\ \text{ft})}{(9\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.4286\ \text{ft})}{(9\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.03102\ \text{kip}$$

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

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

$$M_{max} = ((-0.0066667\ \text{kip/ft}) \times (36\ \text{in}) \times (9\ \text{ft})) \times \left[\left(\frac{(4.5\ \text{ft})}{(9\ \text{ft})} + \frac{(6.4286\ \text{ft})}{2 \times (9\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.5\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.4286\ \text{ft})}{2 \times (9\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.4286\ \text{ft})}{2 \times (9\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12354\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.554\ \text{kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(1017.9\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -36.793\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-36.793\ \text{in}^2\right), \left(0.0018 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

$$\left(1.8322\ \text{in}^2\right)$$

	$$Ratio = \frac{}{(1.8408\ \text{in}^2)}$$ $$Ratio = 0.99533$$	Status: **PASS** Ratio: **1.000**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$ $$s_{rebar} = Max\left[1.5, \left(1.5 \times (0.625\ \text{in})\right)\right]$$ $$s_{rebar} = 1.5\ \text{in}$$	
	Ties:	
25.7.2.2	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)	
25.7.2.1	s_{ties} - Maximum center-to-center spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), D\right]$$ $$s_{ties} = Min\left[\left(16 \times (0.625\ \text{in})\right), \left(48 \times (0.375\ \text{in})\right), (36\ \text{in})\right]$$ $$s_{ties} = 10\ \text{in}$$	
	Summary: Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.85\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(18.554\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.014797$$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 36\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.554 \text{ kip} \rightarrow 18554 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(18554 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.588 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (77.588 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 77.588 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((77.588 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 75.243 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.5329 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(8.5329\ \mathrm{kip})}{(75.243\ \mathrm{kip})}$$ $$Ratio = 0.1134$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.03102\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.03102\ \mathrm{kip})}{(75.243\ \mathrm{kip})}$$ $$Ratio = 0.00041227$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$ $$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 36.962\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(36.962\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.59591$$	Status: **PASS** Ratio: **0.600**
	Considering z-direction: $M_{max} = 0.12354\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.12354 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0019917$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

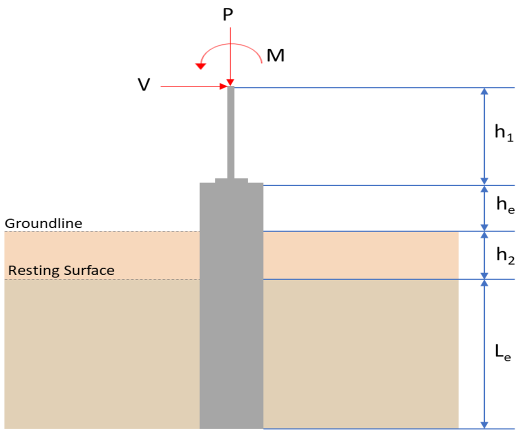
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 9 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.363	18.554
V_x (kip)	-1.050	-1.750
V_z (kip)	0.012	0.020
M_x (kipft)	0.056	0.090
M_z (kipft)	21.690	37.511

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.05 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.35 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(21.69\ \text{kipft}) + ((-1.05\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.23\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.5557\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056\ \text{kipft}) + ((0.012\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.018667\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.4232\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.5557\ \text{ft}), (1.4232\ \text{ft})]$$

$$L_{e,req} = 8.556\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.556\ \text{ft})}{(9\ \text{ft})}$$

$$Ratio = 0.95067$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(12.363 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.749 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.749 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.8745$$

Status: **PASS**
Ratio: **0.870**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 3$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.35 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.23 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.23 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (7.23 \text{ kipft/ft})) + (4 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.1688 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.23 \text{ kipft/ft})) + (3 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]^{\,2}}{(9 \text{ ft})^2 \times [(3 \times (7.23 \text{ kipft/ft})) + (2 \times (-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.35822 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.23 \text{ kipft/ft})) + ((-0.35 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.316 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.1688 \text{ ft})}{2}$$

$$p_a = 0.46266 \text{ kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.35822\ \mathrm{kip/ft^2}\right)}{\left(0.46266\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.77427$$	Status: **PASS** Ratio: **0.770**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$ $$p_s = 1.35\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.316\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.97482$$	Status: **PASS** Ratio: **0.970**
	Considering z-direction: $H_o = 0.004\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.018667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.018667\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (0.004\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (0.018667\ \mathrm{kipft/ft})) + (4 \times (0.004\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$ $$a = 6.4219\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (0.018667\ \mathrm{kipft/ft})) + (3 \times (0.004\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^2}{(9\ \mathrm{ft})^2 \times [(3 \times (0.018667\ \mathrm{kipft/ft})) + (2 \times (0.004\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$ $$p = 0.0037911\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (0.018667\ \mathrm{kipft/ft})) + ((0.004\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$ $$s = 0.0085329\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.4219\ \mathrm{ft})}{2}$$ $$p_a = 0.48164\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0037911\ \mathrm{kip/ft^2}\right)}{\left(0.48164\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.0078713$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

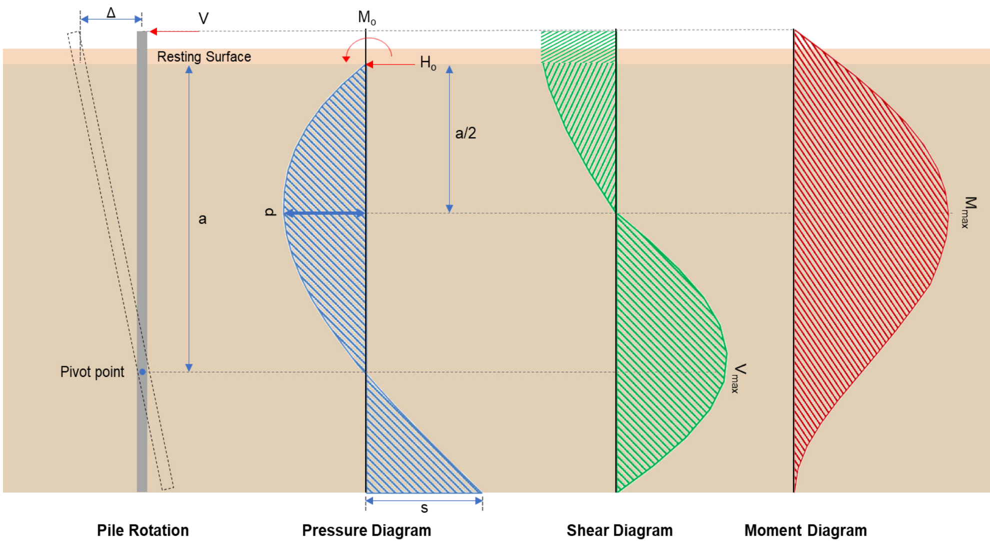
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0085329\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0063207$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.75\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.58333\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.511\ \mathrm{kipft}) + ((-1.75\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 12.504\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.504\ \mathrm{kipft/ft})}{(-0.58333\ \mathrm{kip/ft})}$$

$$E = 21.435\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.504 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (-0.58333 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (12.504 \text{ kipft/ft})) + (4 \times (-0.58333 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.164 \text{ ft}$$

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

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

$$V_{max} = ((-0.58333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.435 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.164 \text{ ft})}{(9 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.435 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.164 \text{ ft})}{(9 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.5329 \text{ kip}$$

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

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

$$M_{max} = ((-0.58333 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(21.435 \text{ ft})}{(9 \text{ ft})} + \frac{(6.164 \text{ ft})}{2 \times (9 \text{ ft})}\right) - \left[\left(\frac{4 \times (21.435 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.164 \text{ ft})}{2 \times (9 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.435 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.164 \text{ ft})}{2 \times (9 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 36.962 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.02 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0066667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.09 \text{ kipft}) + ((0.02 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.03 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.03 \text{ kipft/ft})}{(0.0066667 \text{ kip/ft})}$$

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.03 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (0.0066667 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (0.03 \text{ kipft/ft})) + (4 \times (0.0066667 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.4286 \text{ ft}$$

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

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

$$V_{max} = ((0.0066667\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5\ \mathrm{ft})}{(9\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.4286\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5\ \mathrm{ft})}{(9\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.4286\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.03102\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0066667\ \mathrm{kip/ft}) \times (36\ \mathrm{in}) \times (9\ \mathrm{ft})) \times \left[\left(\frac{(4.5\ \mathrm{ft})}{(9\ \mathrm{ft})} + \frac{(6.4286\ \mathrm{ft})}{2 \times (9\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (4.5\ \mathrm{ft})}{(9\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.4286\ \mathrm{ft})}{2 \times (9\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5\ \mathrm{ft})}{(9\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.4286\ \mathrm{ft})}{2 \times (9\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12354\ \mathrm{kipft}$$

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.554\ \mathrm{kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (1017.9\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (1017.9\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -36.793\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.793\ \mathrm{in}^2), (0.0018 \times (1017.9\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

$$(1.8322\ \mathrm{in}^2)$$

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.554 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.014797$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.554 \text{ kip} \rightarrow 18554 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(18554 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.588 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (77.588 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 77.588 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((77.588 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 75.243 \text{ kip}$$

Considering x-direction:

$V_{max} = 8.5329 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(8.5329\ \mathrm{kip})}{(75.243\ \mathrm{kip})}$$ $$Ratio = 0.1134$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.03102\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.03102\ \mathrm{kip})}{(75.243\ \mathrm{kip})}$$ $$Ratio = 0.00041227$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$ $$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 36.962\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(36.962\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.59591$$	Status: **PASS** Ratio: **0.600**
	Considering z-direction: $M_{max} = 0.12354\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.12354\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.0019917$$	Status: **PASS** Ratio: **0.000**