Project Details

Project Name: Mechanicsville VFD TOP60 10deg - V1Jb
Date: Fri Apr 11 2025

Location: 28165 Hills Club Rd, Mechanicsville, MD 20659, USA
Number of Modules: 60

Number of Poles: 4

Unique ID: 4P-19.75-8TOP-XD-24-L-5Hx12W-GHAB
Date Sold:

Dealer: ______________________________

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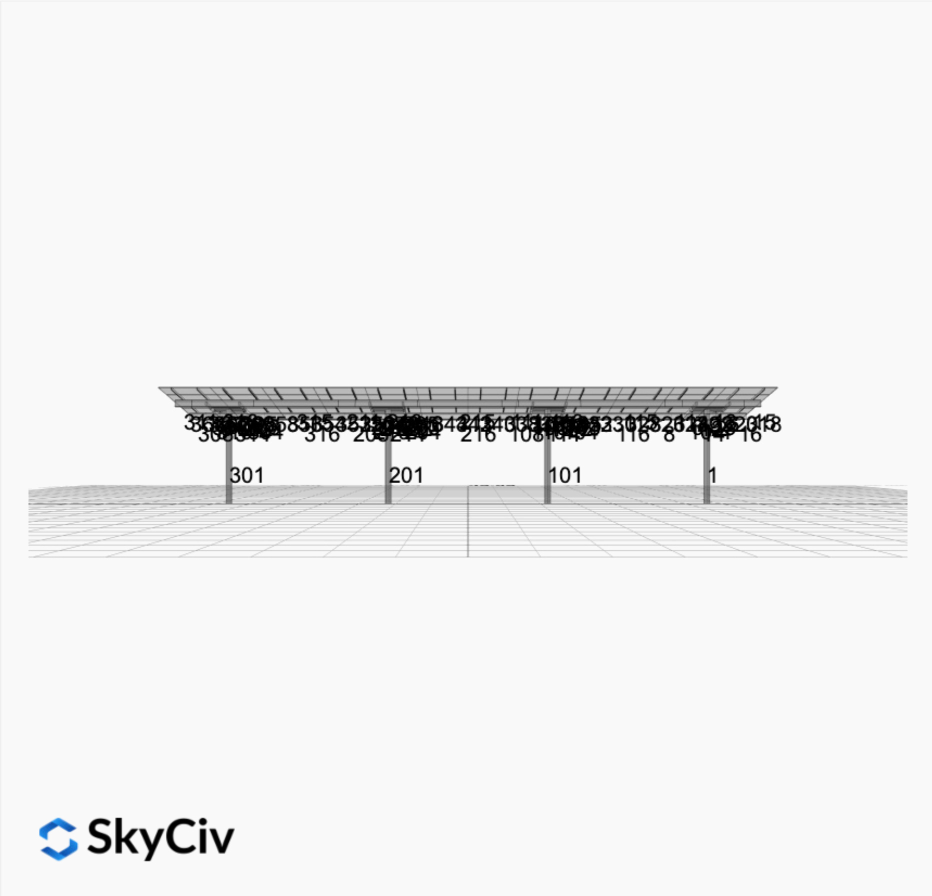


Array Dimensions N/S	18.79 ft
Array Dimensions E/W	71.90 ft
Winter Tilt Angle	10
Front Edge Clearance	10 ft

MT Solar Bill of Materials (4P-19.75-8TOP-XD-24-L-5Hx12W-GHAB)

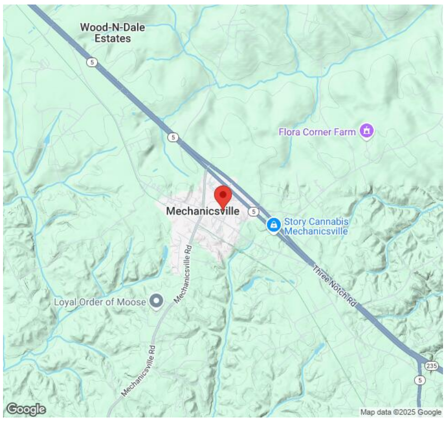
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-24	24IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	12

Rail Bill of Materials

Part	Qty
Rails (226in)	24
Rail Attachment	96

Part	Qty
Module Mid Clamp	96
Module End Clamp	48
Ground Lug	12

Site Details:



Site Address: 28165 Hills Club Rd, Mechanicsville, MD 20659, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	70.90in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Winter Tilt Angle:	10
Front Edge Clearance:	10
Total Array Height at Tilt:	13.26 ft
Total Frame Length:	70.75 ft
Module Info/Notes:	Canadian Solar 455
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	71.90 ft
Rail Length:	225.50 in
Rail Spacing:	3.00 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.63 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.75 ft Pile 2: 8.25 ft Pile 3: 8.25 ft Pile 4: 7.75 ft
Foundation Volume:	8.378 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	28165 Hills Club Rd, Mechanicsville, MD 20659, USA
Wind Speed:	126 mph

Snow Load:	25 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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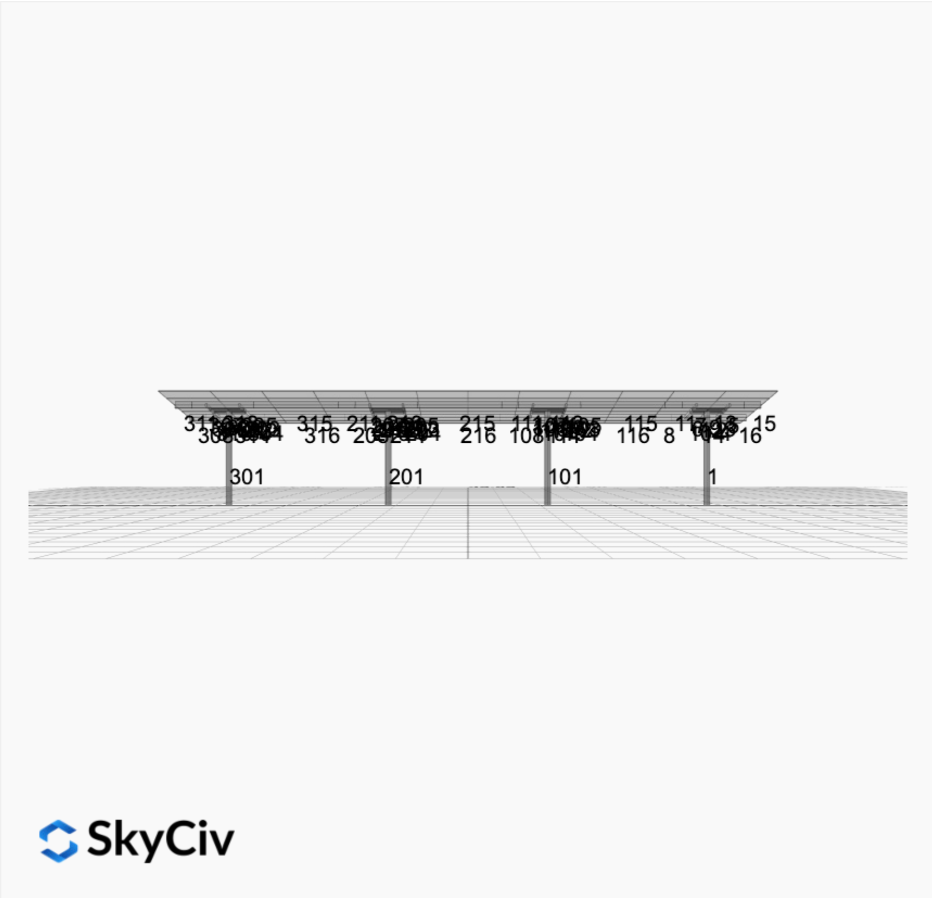
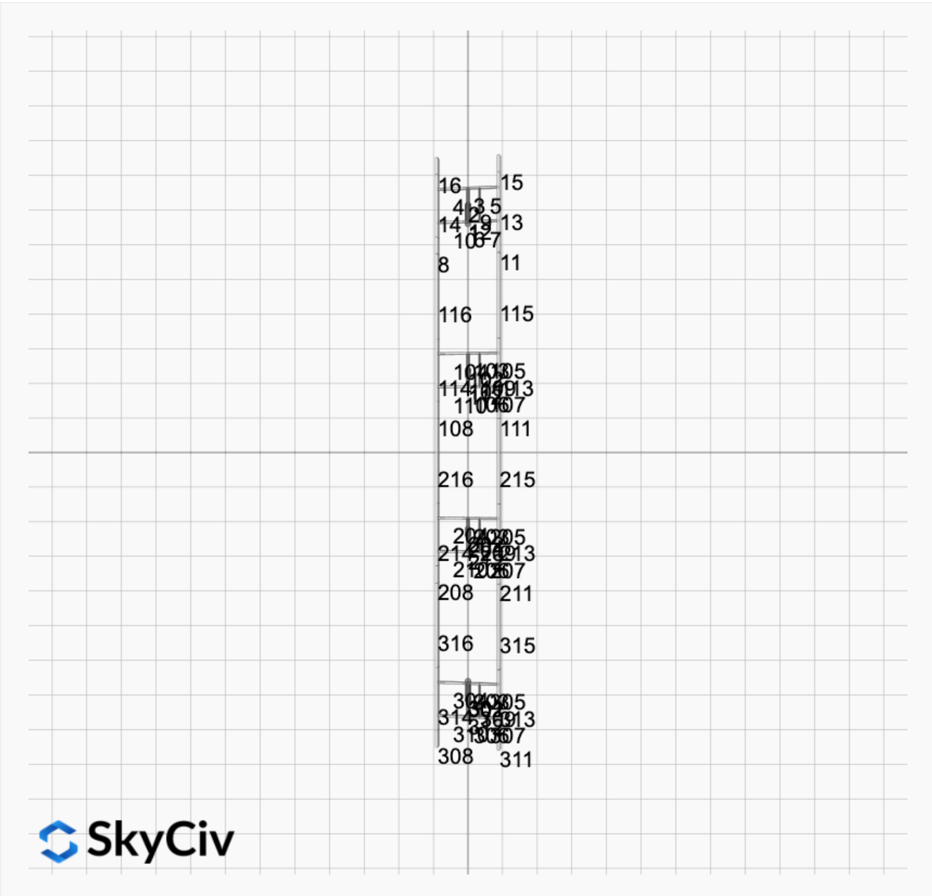
Design Notes:

- 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)




301
9.25
SkyCiv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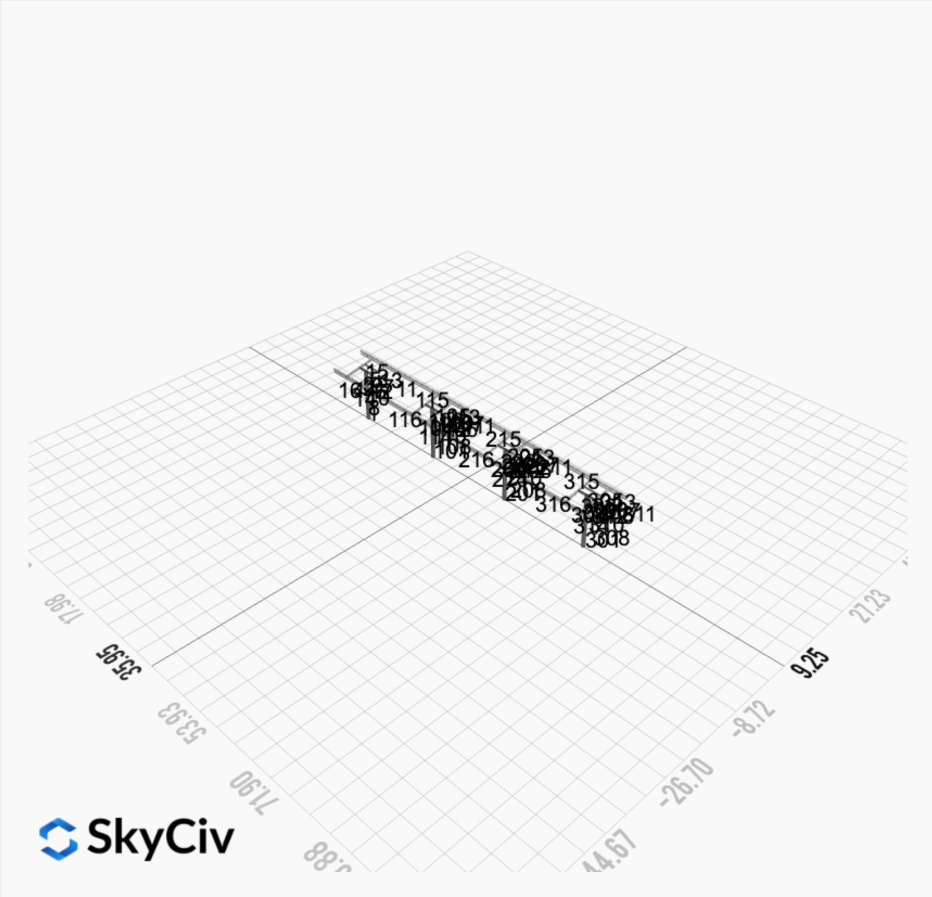
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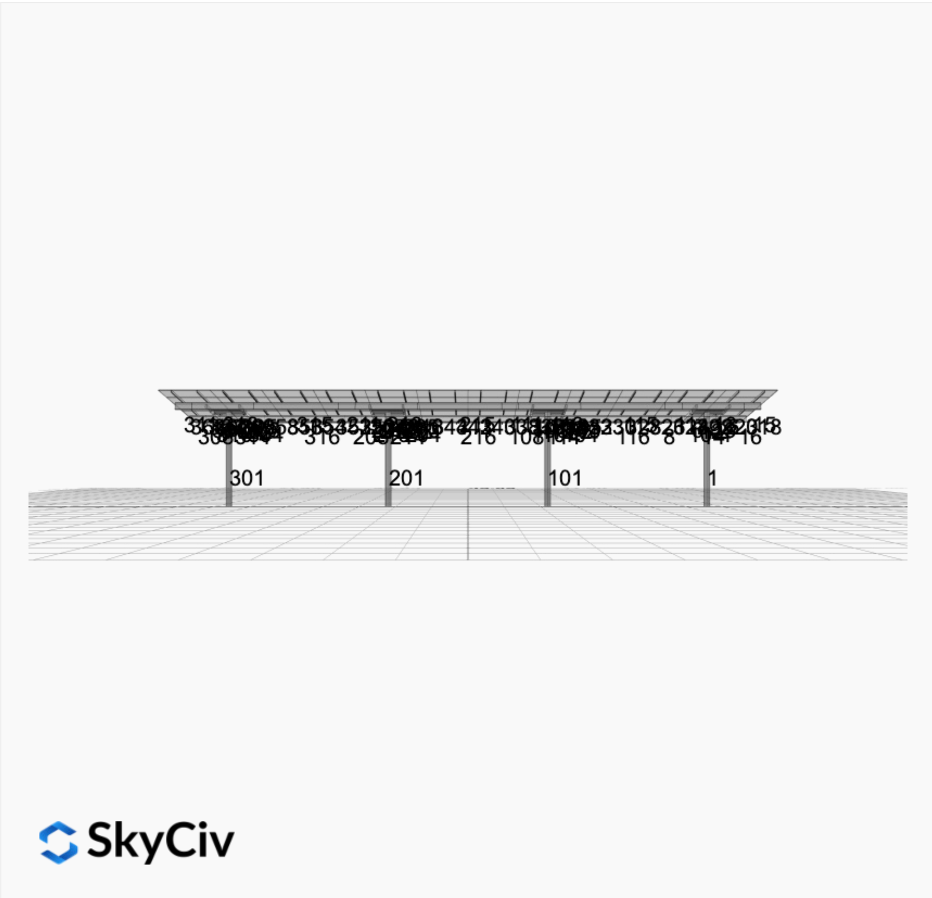
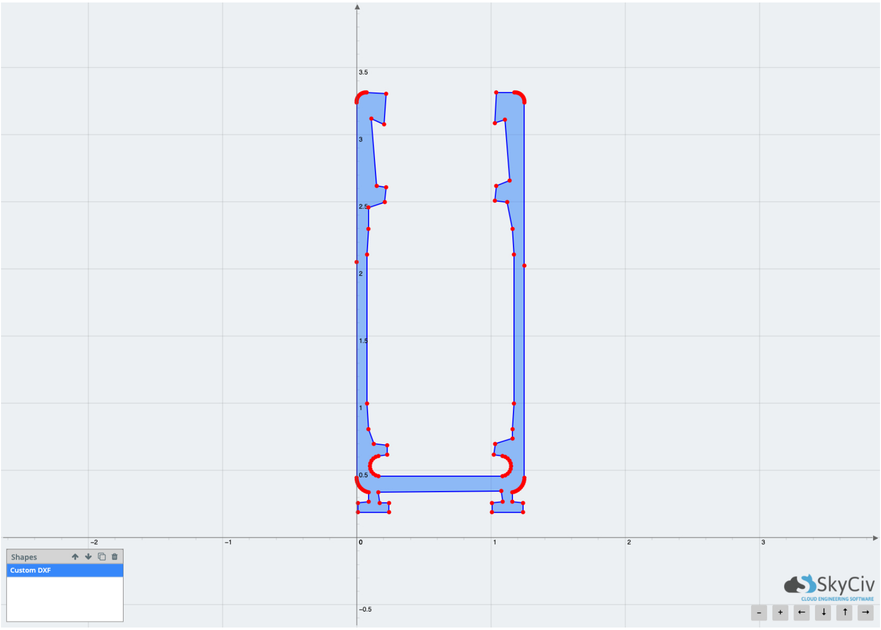
53.93
71.90
21.23
9.25
-8.12
-26.70

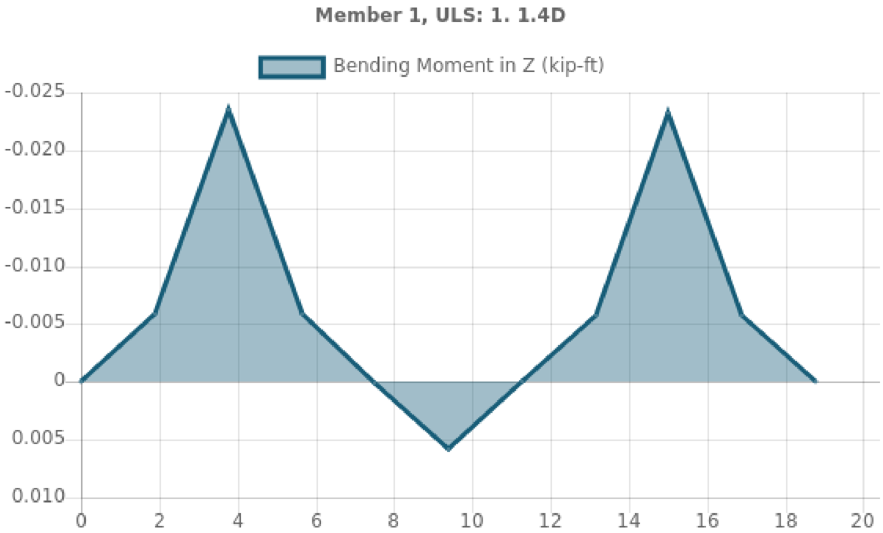

301
201
101
1

Rail Design Check

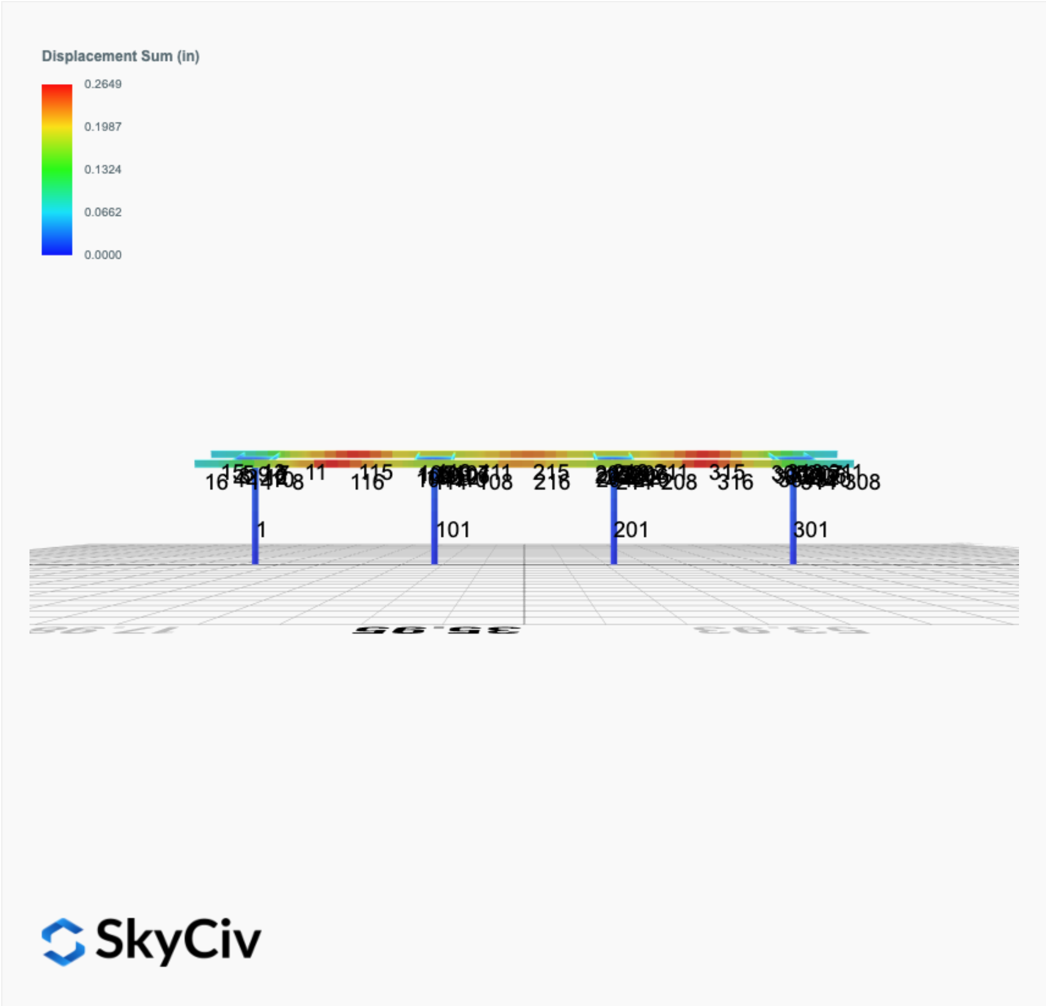
Rail Length: 18.791666666666668 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 2.9958333333333336 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0446 kip/ft
Snow (Y): -0.0079 kip/ft
Wind uplift Case A: 0.0553 kip/ft
Wind uplift Case A: 0.0553 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0788 kip/ft

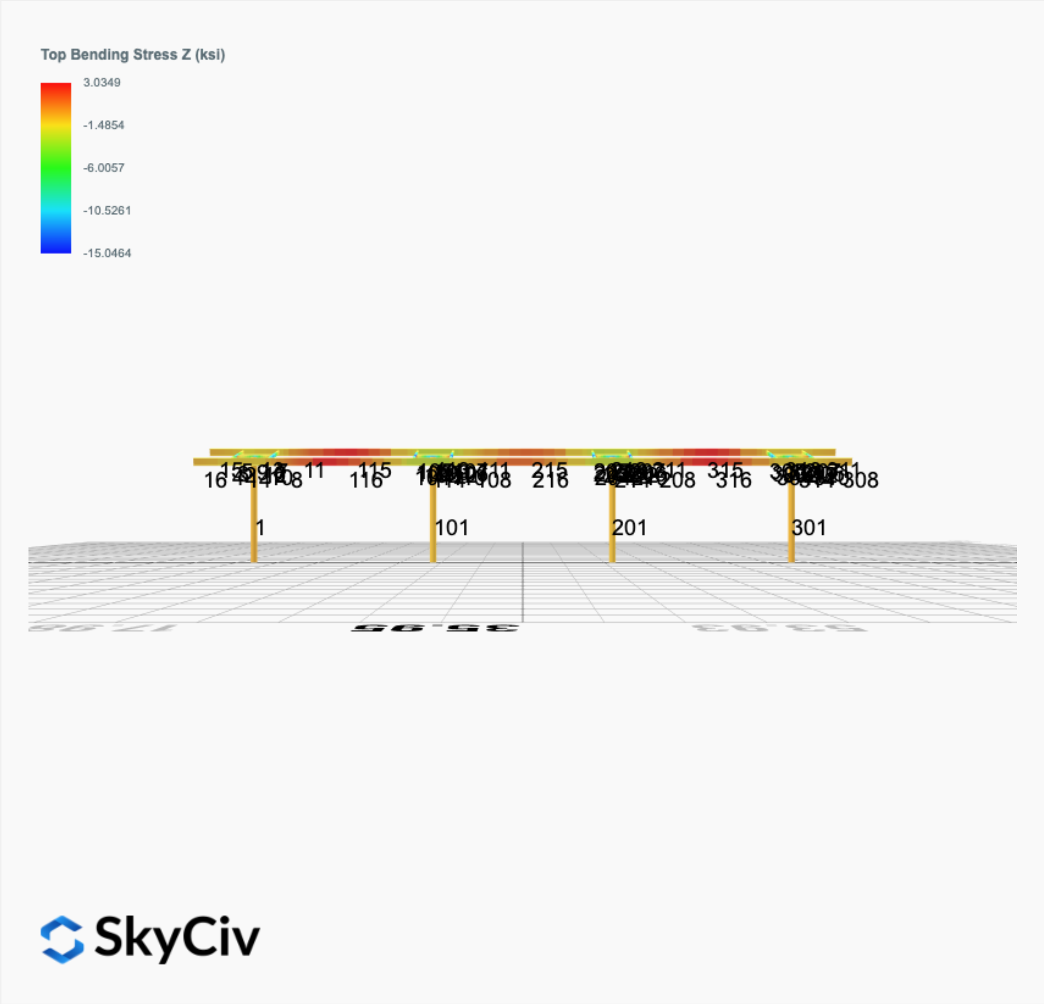


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	12.9404764	0.375	PASS
Material Yield	34.5	12.9404764	0.375	PASS
Material Strength	37	12.9404764	0.350	PASS



FEM Results (Envelope Worst Case for each member)

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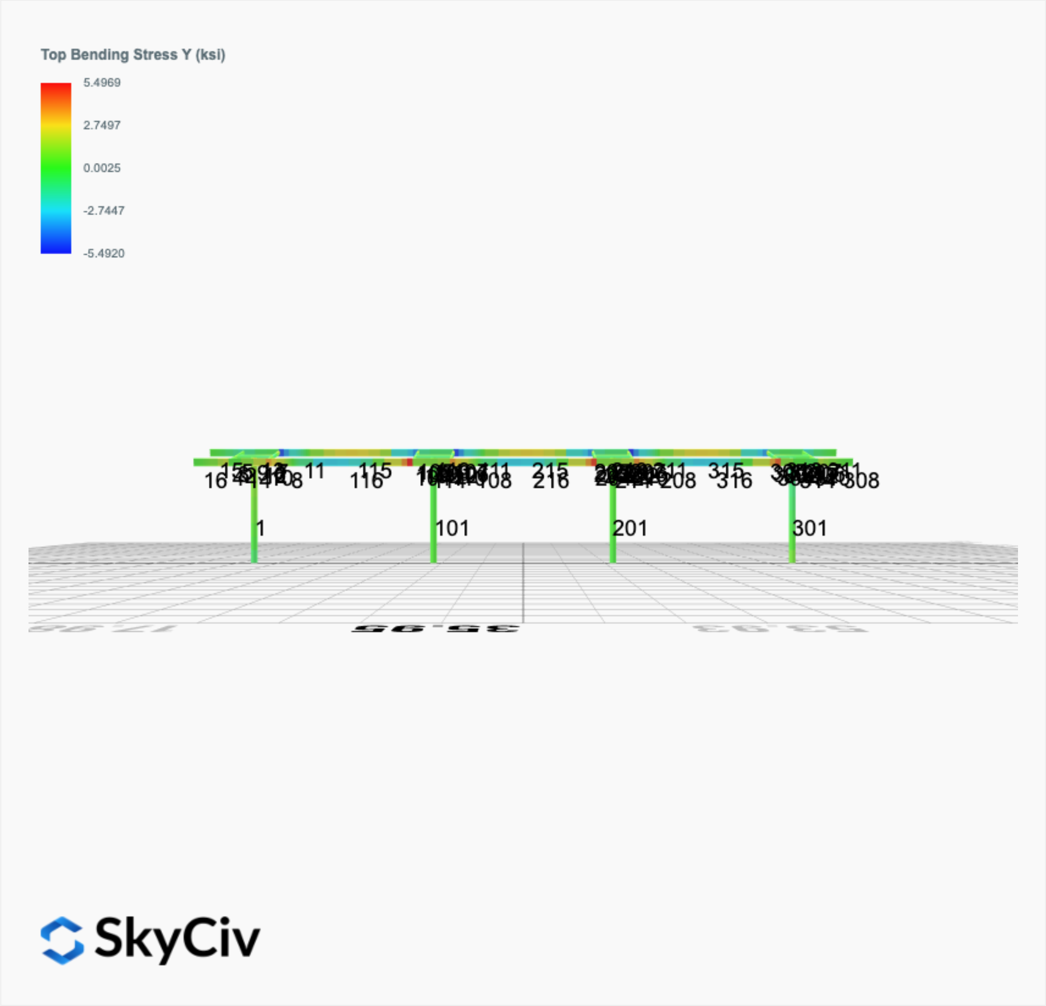
-6.0057
-10.5261
-15.0464
1
101
201
301
SkyCiv


Top Bending Stress Y (ksi)
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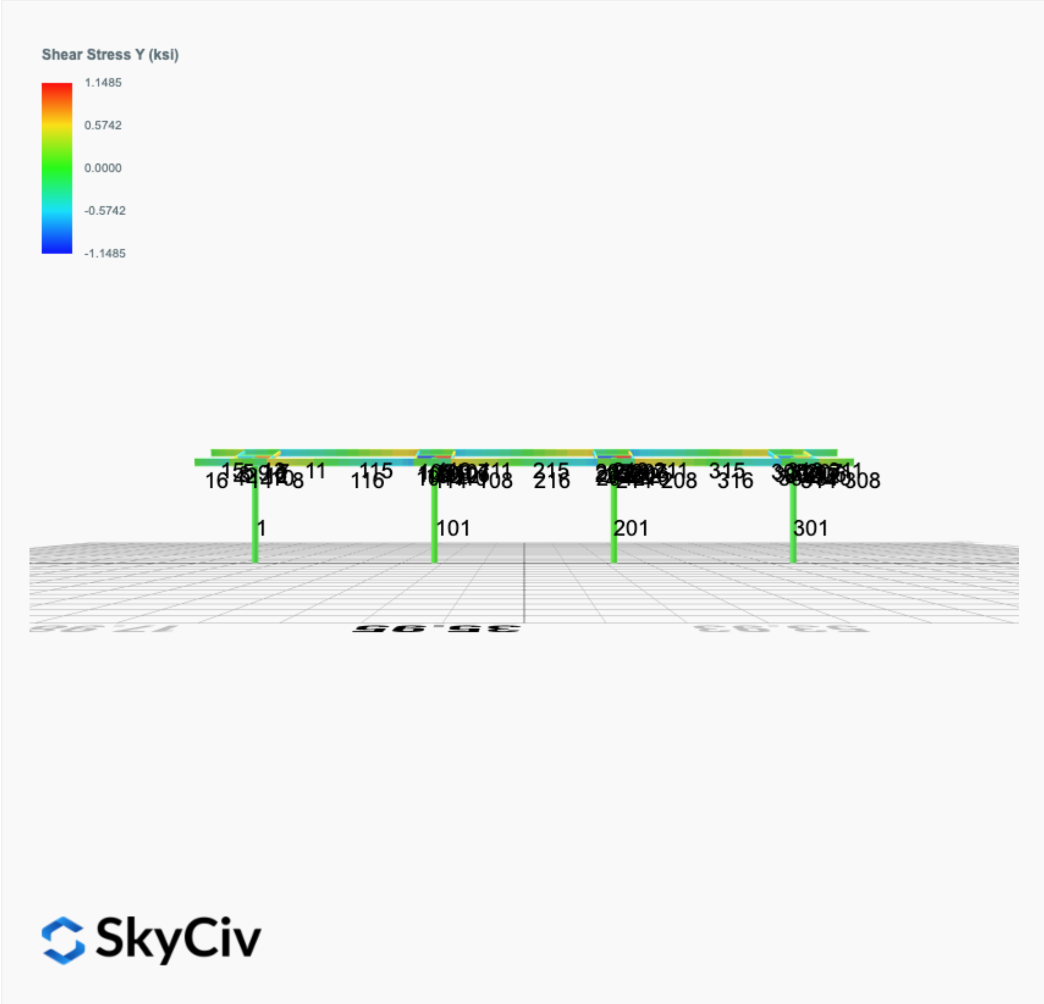
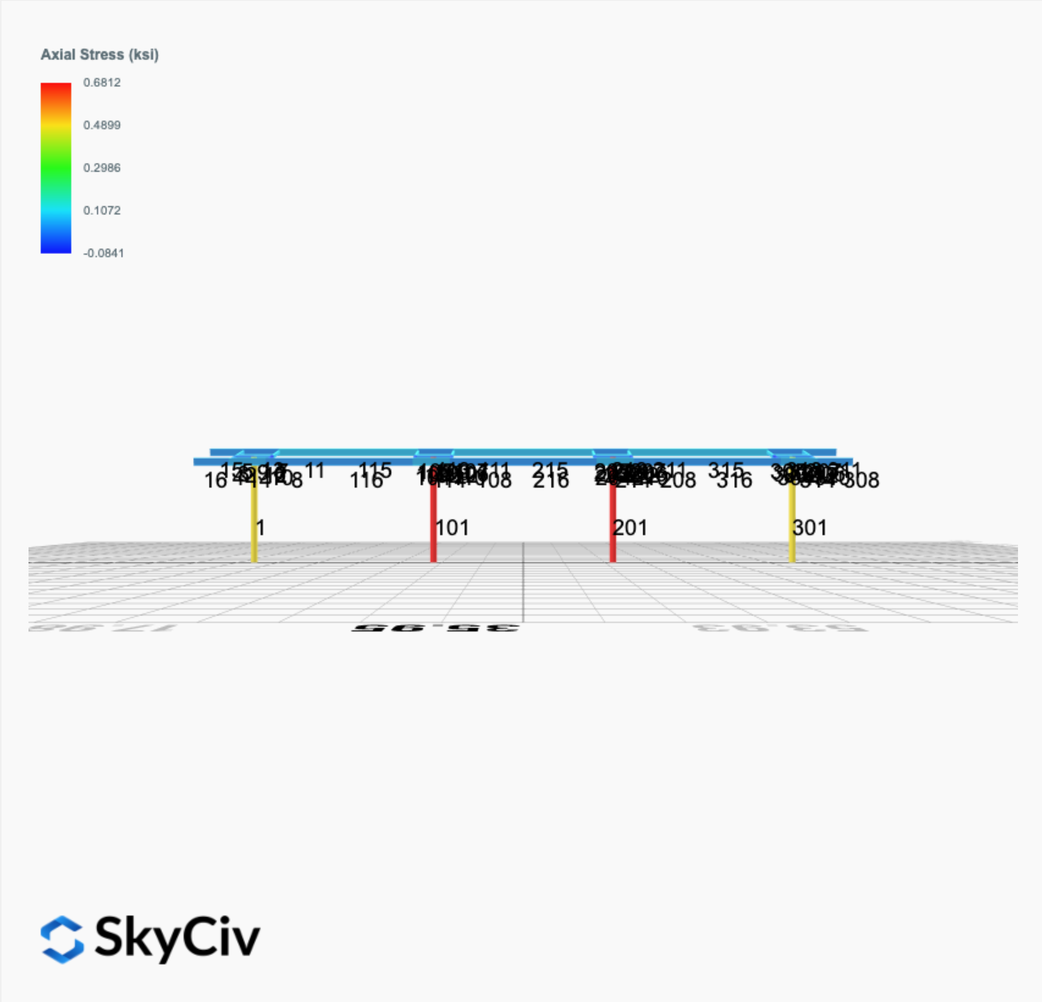
2.7497
0.0025
-2.7447
-5.4920
1
101
201
301
SkyCiv



Shear Stress Y (ksi)
1.1485
0.5742
0.0000
-0.5742
-1.1485
1
101
201
301
SkyCiv


Axial Stress (ksi)
0.6812
0.4899
0.2986
0.1072
-0.0841
1
101
201
301

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	0.0118	2.2550	0.0722	0.2503	-0.0150	-0.0941
ULS: 2. D + L	0.0118	2.2550	0.0722	0.2503	-0.0150	-0.0941
ULS: 3. D + (S or Lr or R)	0.0416	6.4314	0.2554	0.8861	-0.0532	-0.4102
ULS: 3. D + (S or Lr or R)	0.0118	2.2550	0.0722	0.2503	-0.0150	-0.0941
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0341	5.3873	0.2096	0.7271	-0.0436	-0.3312
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0118	2.2550	0.0722	0.2503	-0.0150	-0.0941
ULS: 5b. D + 0.7E	0.0118	2.2550	0.0722	0.2503	-0.0150	-0.0941
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0341	5.3873	0.2096	0.7271	-0.0436	-0.3312
ULS: 8. 0.6D + 0.7E	0.0071	1.3530	0.0433	0.1502	-0.0090	-0.0565
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6518	5.8844	0.2432	0.8361	-0.1512	10.7481
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6518	5.8844	0.2432	0.8361	-0.1512	10.7481
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4644	-0.2849	-0.0401	-0.1339	0.0670	-3.1584
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4352	0.0321	-0.0420	-0.1389	0.0872	-13.6255
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4636	8.1094	0.3379	1.1665	-0.1458	7.8005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4636	8.1094	0.3379	1.1665	-0.1458	7.8005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3736	3.4824	0.1254	0.4390	0.0178	-2.6294
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3517	3.7201	0.1239	0.4352	0.0330	-10.4797
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4859	4.9770	0.2005	0.6896	-0.1171	8.0375
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4859	4.9770	0.2005	0.6896	-0.1171	8.0375
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3513	0.3501	-0.0120	-0.0379	0.0465	-2.3923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3294	0.5878	-0.0135	-0.0416	0.0617	-10.2426
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6565	4.9824	0.2144	0.7360	-0.1452	10.7857
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6565	4.9824	0.2144	0.7360	-0.1452	10.7857
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4597	-1.1869	-0.0690	-0.2340	0.0729	-3.1207
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4305	-0.8699	-0.0709	-0.2391	0.0932	-13.5878

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.4129
Shear X	-1.1060
Shear Z	0.5244
Moment X	1.8169
Moment Y (Twist)	0.2659
Moment Z	23.3018

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.1094
Shear X	-0.6565
Shear Z	0.3379
Moment X	1.1665
Moment Y (Twist)	0.1512
Moment Z	13.6255

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	-0.0118	2.8657	-0.0097	-0.0342	0.0060	0.1599
ULS: 2. D + L	-0.0118	2.8657	-0.0097	-0.0342	0.0060	0.1599
ULS: 3. D + (S or Lr or R)	-0.0416	8.5876	-0.0344	-0.1210	0.0211	0.4955
ULS: 3. D + (S or Lr or R)	-0.0118	2.8657	-0.0097	-0.0342	0.0060	0.1599
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0341	7.1571	-0.0282	-0.0993	0.0173	0.4116

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0118	2.8657	-0.0097	-0.0342	0.0060	0.1599
ULS: 5b. D + 0.7E	-0.0118	2.8657	-0.0097	-0.0342	0.0060	0.1599
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0341	7.1571	-0.0282	-0.0993	0.0173	0.4116
ULS: 8. 0.6D + 0.7E	-0.0071	1.7194	-0.0058	-0.0205	0.0036	0.0959
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.8638	7.8318	-0.0255	-0.0913	0.0007	13.9526
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.8638	7.8318	-0.0255	-0.0913	0.0007	13.9526
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.5985	-0.6225	0.0053	0.0185	-0.0010	-3.9647
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4899	-0.1580	-0.0054	-0.0169	0.0241	-16.4982
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6731	10.8817	-0.0401	-0.1421	0.0134	10.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6731	10.8817	-0.0401	-0.1421	0.0134	10.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4236	4.5410	-0.0170	-0.0598	0.0121	-2.6818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3421	4.8894	-0.0250	-0.0863	0.0309	-12.0819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6508	6.5903	-0.0216	-0.0770	0.0020	10.5044
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6508	6.5903	-0.0216	-0.0770	0.0020	10.5044
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4459	0.2496	0.0015	0.0053	0.0008	-2.9335
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3645	0.5979	-0.0065	-0.0212	0.0196	-12.3337
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.8591	6.6855	-0.0216	-0.0776	-0.0017	13.8886
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.8591	6.6855	-0.0216	-0.0776	-0.0017	13.8886
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6032	-1.7687	0.0092	0.0321	-0.0033	-4.0286
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4946	-1.3043	-0.0015	-0.0032	0.0217	-16.5621

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	16.7322
Shear X	-1.4476
Shear Z	-0.0642
Moment X	-0.2277
Moment Y (Twist)	0.0486
Moment Z	28.1014

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	10.8817
Shear X	-0.8638
Shear Z	-0.0401
Moment X	-0.1421
Moment Y (Twist)	0.0309
Moment Z	16.5621

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	-0.0118	2.8657	0.0097	0.0342	-0.0060	0.1599
ULS: 2. D + L	-0.0118	2.8657	0.0097	0.0342	-0.0060	0.1599
ULS: 3. D + (S or Lr or R)	-0.0416	8.5876	0.0344	0.1210	-0.0210	0.4955
ULS: 3. D + (S or Lr or R)	-0.0118	2.8657	0.0097	0.0342	-0.0060	0.1599
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0341	7.1571	0.0282	0.0993	-0.0172	0.4116
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0118	2.8657	0.0097	0.0342	-0.0060	0.1599
ULS: 5b. D + 0.7E	-0.0118	2.8657	0.0097	0.0342	-0.0060	0.1599
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0341	7.1571	0.0282	0.0993	-0.0172	0.4116
ULS: 8. 0.6D + 0.7E	-0.0071	1.7194	0.0058	0.0205	-0.0036	0.0959
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.8638	7.8318	0.0255	0.0913	-0.0007	13.9526
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.8638	7.8318	0.0255	0.0913	-0.0007	13.9526
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.5985	-0.6225	-0.0053	-0.0185	0.0010	-3.9647
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4899	-0.1580	0.0054	0.0169	-0.0241	-16.4982

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	-0.6731	10.8817	0.0401	0.1421	-0.0133	10.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6731	10.8817	0.0401	0.1421	-0.0133	10.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4236	4.5410	0.0170	0.0598	-0.0120	-2.6818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3421	4.8894	0.0250	0.0863	-0.0308	-12.0819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6508	6.5903	0.0216	0.0770	-0.0020	10.5044
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6508	6.5903	0.0216	0.0770	-0.0020	10.5044
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.4459	0.2496	-0.0015	-0.0053	-0.0008	-2.9335
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3645	0.5979	0.0065	0.0212	-0.0196	-12.3337
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.8591	6.6855	0.0216	0.0776	0.0017	13.8886
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.8591	6.6855	0.0216	0.0776	0.0017	13.8886
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.6032	-1.7687	-0.0092	-0.0321	0.0034	-4.0286
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4946	-1.3043	0.0015	0.0032	-0.0217	-16.5621

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	16.7322
Shear X	-1.4476
Shear Z	0.0642
Moment X	0.2277
Moment Y (Twist)	0.0484
Moment Z	28.1014

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	10.8817
Shear X	-0.8638
Shear Z	0.0401
Moment X	0.1421
Moment Y (Twist)	0.0308
Moment Z	16.5621

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	0.0118	2.2550	-0.0722	-0.2503	0.0150	-0.0941
ULS: 2. D + L	0.0118	2.2550	-0.0722	-0.2503	0.0150	-0.0941
ULS: 3. D + (S or Lr or R)	0.0416	6.4314	-0.2554	-0.8861	0.0532	-0.4101
ULS: 3. D + (S or Lr or R)	0.0118	2.2550	-0.0722	-0.2503	0.0150	-0.0941
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0341	5.3873	-0.2096	-0.7271	0.0437	-0.3311
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0118	2.2550	-0.0722	-0.2503	0.0150	-0.0941
ULS: 5b. D + 0.7E	0.0118	2.2550	-0.0722	-0.2503	0.0150	-0.0941
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0341	5.3873	-0.2096	-0.7271	0.0437	-0.3311
ULS: 8. 0.6D + 0.7E	0.0071	1.3530	-0.0433	-0.1502	0.0090	-0.0565
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6518	5.8844	-0.2432	-0.8361	0.1512	10.7481
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6518	5.8844	-0.2432	-0.8361	0.1512	10.7481
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4644	-0.2849	0.0401	0.1339	-0.0670	-3.1584
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4352	0.0321	0.0420	0.1390	-0.0872	-13.6255
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4636	8.1094	-0.3379	-1.1665	0.1458	7.8005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4636	8.1094	-0.3379	-1.1665	0.1458	7.8005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3736	3.4824	-0.1254	-0.4390	-0.0178	-2.6293
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3517	3.7201	-0.1239	-0.4352	-0.0330	-10.4796
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4859	4.9770	-0.2005	-0.6896	0.1171	8.0375
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4859	4.9770	-0.2005	-0.6896	0.1171	8.0375
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3513	0.3501	0.0120	0.0379	-0.0465	-2.3923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3294	0.5878	0.0135	0.0417	-0.0616	-10.2426

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6565	4.9824	-0.2144	-0.7360	0.1452	10.7857
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6565	4.9824	-0.2144	-0.7360	0.1452	10.7857
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4597	-1.1869	0.0690	0.2340	-0.0729	-3.1207
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4305	-0.8699	0.0709	0.2391	-0.0932	-13.5878

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.4129
Shear X	-1.1060
Shear Z	-0.5244
Moment X	-1.8169
Moment Y (Twist)	0.2660
Moment Z	23.3020

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.1094
Shear X	-0.6565
Shear Z	-0.3379
Moment X	-1.1665
Moment Y (Twist)	0.1512
Moment Z	13.6255

Project Details

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

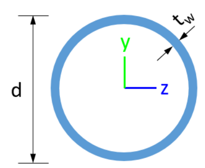
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

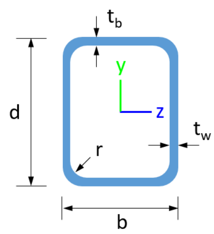
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

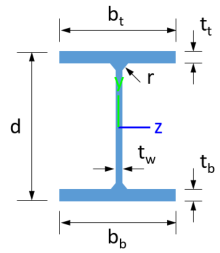
Section Dimensions



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	24.43	24.43	11.63	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.16,1.18,1.18,1.15,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.24,1.16,1.18,1.18,1.16,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.62,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.58,1.69,1.67,1.67,1.66,1.69	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.76,1.65,1.67,1.67,1.65,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.24,1.17,1.18,1.18,1.17,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.75,1.65,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.28,1.28,1.28,1.28,1.28,1.28,1.27,1.27,1.33,1.39,1.26,1.26,1.30,1.56,1.28,1.28,1.28,1.31,1.27,1.27,1.33,1.39,1.26,1.26,1.30,1.73	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.66,1.69	300	200	1
11	20	1.33	1.33	2.05	1.29,1.29,1.29,1.30,1.29,1.29,1.32,1.32,1.38,1.47,1.32,1.32,1.26,1.39,1.30,1.30,1.30,1.25,1.32,1.32,1.40,1.46,1.32,1.32,1.27,1.38	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.40,1.32,1.23,1.23,1.17,1.27,1.23,1.23,1.24,1.22,1.23,1.23,1.39,1.32,1.23,1.23,1.18,1.27	300	200	1
14	20	4.88	4.00	7.50	1.23,1.23,1.23,1.23,1.23,1.23,1.22,1.22,1.36,1.34,1.21,1.21,1.28,1.55,1.23,1.23,1.22,1.26,1.22,1.22,1.37,1.33,1.21,1.21,1.27,1.78	300	200	1
15	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	24.43	24.43	11.63	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.20,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.23,1.17,1.18,1.18,1.17,1.18	300	200	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.69,1.67,1.67,1.66,1.69	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.65,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.20,1.17,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.23,1.17,1.18,1.18,1.17,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.65,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.23,2.25,2.23,2.26,2.24,2.23,2.35,2.35,2.08,1.83,2.33,2.33,2.11,1.46,2.39,2.39,2.34,2.10,2.35,2.35,2.08,1.80,2.33,2.33,2.11,1.36	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.69	300	200	1
111	20	1.33	1.33	2.05	2.11,2.12,2.11,2.12,2.11,2.11,2.08,2.08,2.06,1.54,2.08,2.08,2.36,1.78,2.10,2.10,2.11,2.28,2.08,2.08,1.98,1.56,2.08,2.08,2.38,1.82	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.18,1.26,1.06,1.06,1.05,1.10,1.06,1.06,1.06,1.04,1.06,1.06,1.18,1.26,1.06,1.06,1.05,1.09	300	200	1
114	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.10,1.13,1.05,1.05,1.06,1.68,1.05,1.05,1.05,1.06,1.05,1.05,1.10,1.13,1.05,1.05,1.06,3.48	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.13,1.09,1.14,1.14,1.17,1.12,1.15,1.15,1.15,1.19,1.14,1.14,1.12,1.10,1.14,1.14,1.16,1.12	300	200	1
116	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.14,1.12,1.17,1.17,1.15,1.08,1.16,1.16,1.16,1.15,1.17,1.17,1.14,1.12,1.17,1.17,1.15,1.08	300	200	1
201	9	24.43	24.43	11.63	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.20,1.17,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.23,1.17,1.18,1.18,1.17,1.18	300	200	1
204	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.68,1.67,1.67,1.66,1.69	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.65,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.20,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.23,1.17,1.18,1.18,1.17,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.70,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.74,1.65,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.09,2.09,1.77,1.54,2.09,2.09,1.96,1.32,2.08,2.08,2.07,1.90,2.09,2.09,1.80,1.53,2.09,2.09,1.97,1.24	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.61,1.69,1.67,1.67,1.66,1.69	300	200	1
211	20	1.33	1.33	2.05	2.02,2.02,2.02,2.02,2.02,2.02,1.82,1.82,1.67,1.38,1.79,1.79,2.09,1.52,1.92,1.92,2.00,2.12,1.83,1.83,1.61,1.39,1.78,1.78,2.08,1.54	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.18,1.26,1.06,1.06,1.05,1.10,1.06,1.06,1.06,1.04,1.06,1.06,1.18,1.26,1.06,1.06,1.05,1.09	300	200	1
214	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.10,1.13,1.05,1.05,1.06,1.68,1.05,1.05,1.05,1.06,1.05,1.05,1.10,1.13,1.05,1.05,1.06,3.48	300	200	1
215	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.14,1.11,1.15,1.15,1.18,1.13,1.16,1.16,1.17,1.21,1.16,1.16,1.14,1.12,1.15,1.15,1.18,1.13	300	200	1
216	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.19,1.19,1.15,1.13,1.19,1.19,1.17,1.11,1.18,1.18,1.18,1.16,1.18,1.18,1.16,1.13,1.19,1.19,1.17,1.09	300	200	1
301	9	24.43	24.43	11.63	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.21,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.24,1.17,1.18,1.18,1.17,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.60,1.69,1.67,1.67,1.66,1.69	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.75,1.65,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.21,1.16,1.18,1.18,1.15,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.24,1.16,1.18,1.18,1.16,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.66,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.76,1.65,1.67,1.67,1.65,1.66	300	200	1
308	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.62,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.58,1.69,1.67,1.67,1.66,1.69	300	200	1
311	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.40,1.32,1.23,1.23,1.17,1.27,1.23,1.23,1.24,1.22,1.23,1.23,1.39,1.32,1.23,1.23,1.18,1.27	300	200	1
314	20	4.88	4.00	7.50	1.23,1.23,1.23,1.23,1.23,1.23,1.22,1.22,1.36,1.33,1.21,1.21,1.28,1.55,1.23,1.23,1.22,1.25,1.22,1.22,1.37,1.33,1.21,1.21,1.27,1.78	300	200	1

315	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.11,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.09,1.11,1.08,1.08,1.08,1.09	300	200	1
316	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.14	300	200	1

Member Design Capacity

Member ID	Φ_tP_n (kip)	Φ_cP_n (kip)	Φ_bM_{zn} (k-ft)	Φ_bM_{yn} (k-ft)	Φ_vV_{yn} (kip)	Φ_vV_{zn} (kip)
1	377.97	182.53	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	35.68	6.46	56.26	44.91
14	159.30	97.43	37.04	6.46	56.26	44.91
15	159.30	113.66	46.90	6.46	56.26	44.91
16	159.30	113.66	46.90	6.46	56.26	44.91
101	377.97	182.53	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	31.92	6.46	56.26	44.91
114	159.30	97.43	32.11	6.46	56.26	44.91
115	159.30	75.13	21.07	6.46	56.26	44.91
116	159.30	75.13	20.73	6.46	56.26	44.91
201	377.97	182.53	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	31.92	6.46	56.26	44.91
214	159.30	97.43	32.11	6.46	56.26	44.91
215	159.30	75.13	21.45	6.46	56.26	44.91
216	159.30	75.13	21.07	6.46	56.26	44.91
301	377.97	182.53	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	113.66	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	113.66	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	35.68	6.46	56.26	44.91
314	159.30	97.43	37.05	6.46	56.26	44.91
315	159.30	75.13	20.88	6.46	56.26	44.91
316	159.30	75.13	20.88	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	0.068	0.280	0.051	0.010	0.005	0.283	#16	0.499	Not Required	Pass
2	0.001	0.299	0.036	0.068	0.007	0.327	#21	0.054	Not Required	Pass
3	0.003	0.499	0.008	0.049	0.003	0.507	#21	0.046	Not Required	Pass
4	0.001	0.445	0.037	0.045	0.009	0.483	#21	0.122	Not Required	Pass
5	0.002	0.309	0.015	0.050	0.003	0.314	#21	0.076	Not Required	Pass
6	0.003	0.654	0.046	0.067	0.012	0.701	#21	0.046	Not Required	Pass
7	0.003	0.405	0.066	0.065	0.017	0.425	#21	0.076	Not Required	Pass
8	0.002	0.115	0.067	0.035	0.007	0.149	#21	0.102	Not Required	Pass
9	0.003	0.077	0.039	0.003	0.003	0.117	#21	0.206	Not Required	Pass
10	0.004	0.580	0.052	0.058	0.011	0.594	#21	0.082	Not Required	Pass
11	0.003	0.124	0.071	0.040	0.007	0.154	#21	0.102	Not Required	Pass
12	0.001	0.457	0.046	0.091	0.008	0.491	#21	0.054	Not Required	Pass
13	0.004	0.105	0.170	0.053	0.009	0.210	#21	0.306	Not Required	Pass
14	0.003	0.093	0.165	0.046	0.009	0.212	#24	0.204	Not Required	Pass
15	0.000	0.017	0.016	0.015	0.002	0.033	#21	Not Required	Not Required	Pass
16	0.000	0.016	0.016	0.013	0.002	0.031	#21	Not Required	Not Required	Pass
101	0.092	0.337	0.006	0.013	0.001	0.342	#16	0.499	Not Required	Pass
102	0.001	0.531	0.057	0.110	0.009	0.578	#21	0.054	Not Required	Pass
103	0.003	0.788	0.024	0.079	0.003	0.814	#21	0.046	Not Required	Pass
104	0.004	0.719	0.061	0.072	0.013	0.759	#21	0.082	Not Required	Pass
105	0.003	0.489	0.065	0.078	0.017	0.506	#21	0.076	Not Required	Pass
106	0.003	0.774	0.020	0.077	0.003	0.792	#21	0.046	Not Required	Pass
107	0.003	0.480	0.057	0.077	0.015	0.495	#21	0.076	Not Required	Pass
108	0.002	0.046	0.060	0.040	0.007	0.106	#21	0.102	Not Required	Pass
109	0.006	0.079	0.021	0.001	0.000	0.102	#21	0.206	Not Required	Pass
110	0.003	0.697	0.058	0.070	0.013	0.739	#21	0.082	Not Required	Pass

111	0.003	0.050	0.061	0.044	0.007	0.103	#21	0.102	Not Required	Pass
112	0.001	0.512	0.057	0.107	0.010	0.558	#21	0.054	Not Required	Pass
113	0.004	0.239	0.175	0.062	0.009	0.380	#21	0.306	Not Required	Pass
114	0.005	0.237	0.175	0.057	0.009	0.377	#21	0.306	Not Required	Pass
115	0.006	0.371	0.086	0.049	0.007	0.459	#21	0.507	Not Required	Pass
116	0.003	0.328	0.088	0.045	0.007	0.416	#21	0.507	Not Required	Pass
201	0.092	0.337	0.006	0.013	0.001	0.342	#16	0.499	Not Required	Pass
202	0.001	0.512	0.057	0.107	0.010	0.558	#21	0.054	Not Required	Pass
203	0.003	0.774	0.020	0.077	0.003	0.792	#21	0.046	Not Required	Pass
204	0.003	0.697	0.058	0.070	0.013	0.739	#21	0.082	Not Required	Pass
205	0.003	0.480	0.057	0.077	0.015	0.495	#21	0.076	Not Required	Pass
206	0.003	0.788	0.024	0.079	0.003	0.814	#21	0.046	Not Required	Pass
207	0.003	0.489	0.065	0.078	0.017	0.506	#21	0.076	Not Required	Pass
208	0.002	0.064	0.075	0.045	0.007	0.106	#21	0.102	Not Required	Pass
209	0.006	0.079	0.021	0.001	0.000	0.102	#21	0.206	Not Required	Pass
210	0.004	0.719	0.061	0.072	0.013	0.759	#21	0.082	Not Required	Pass
211	0.003	0.079	0.075	0.049	0.007	0.100	#21	0.102	Not Required	Pass
212	0.001	0.531	0.057	0.110	0.009	0.578	#21	0.054	Not Required	Pass
213	0.004	0.239	0.175	0.062	0.009	0.380	#21	0.306	Not Required	Pass
214	0.005	0.237	0.175	0.057	0.009	0.377	#21	0.306	Not Required	Pass
215	0.005	0.256	0.086	0.044	0.007	0.345	#21	0.507	Not Required	Pass
216	0.003	0.210	0.086	0.040	0.007	0.297	#21	0.507	Not Required	Pass
301	0.068	0.280	0.051	0.010	0.005	0.283	#16	0.499	Not Required	Pass
302	0.001	0.457	0.046	0.091	0.008	0.491	#21	0.054	Not Required	Pass
303	0.003	0.654	0.046	0.067	0.012	0.701	#21	0.046	Not Required	Pass
304	0.004	0.580	0.052	0.058	0.011	0.594	#21	0.082	Not Required	Pass
305	0.003	0.405	0.066	0.065	0.017	0.425	#21	0.076	Not Required	Pass
306	0.003	0.499	0.008	0.049	0.003	0.507	#21	0.046	Not Required	Pass
307	0.002	0.309	0.015	0.050	0.003	0.314	#21	0.076	Not Required	Pass
308	0.000	0.016	0.016	0.013	0.002	0.031	#21	Not Required	Not Required	Pass
309	0.003	0.077	0.039	0.003	0.003	0.117	#21	0.206	Not Required	Pass
310	0.001	0.445	0.037	0.045	0.009	0.483	#21	0.122	Not Required	Pass
311	0.000	0.017	0.016	0.015	0.002	0.033	#21	Not Required	Not Required	Pass
312	0.001	0.299	0.036	0.068	0.007	0.327	#21	0.054	Not Required	Pass
313	0.004	0.105	0.170	0.053	0.009	0.210	#21	0.204	Not Required	Pass
314	0.003	0.093	0.165	0.046	0.009	0.212	#24	0.306	Not Required	Pass
315	0.006	0.392	0.086	0.040	0.007	0.479	#21	0.507	Not Required	Pass
316	0.003	0.353	0.087	0.035	0.007	0.440	#21	0.507	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

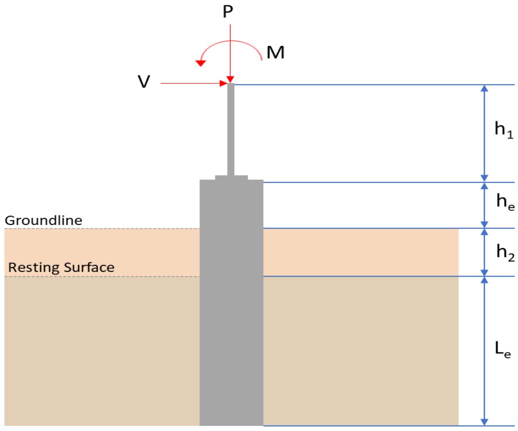
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round

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

$L = 7.75\ \text{ft}$ - 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)	8.109	12.413
V_x (kip)	-0.657	-1.106
V_z (kip)	0.338	0.524
M_x (kipft)	1.167	1.817
M_z (kipft)	13.625	23.302

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,

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

$$H_o = \frac{(-0.657\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.219\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.625\ \text{kipft}) + ((-0.657\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 4.5417\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.4684\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.338\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.11267\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.167\ \text{kipft}) + ((0.338\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.389\ \text{kipft/ft}$$

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:
$L_{e,z} = 4.6076\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.4684\ \text{ft}), (4.6076\ \text{ft})]$$

$$L_{e,req} = 7.468\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.468\ \text{ft})}{(7.75\ \text{ft})}$$

$$Ratio = 0.96361$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(8.109\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.1472\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.1472\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.57359$$

Status: **PASS**
Ratio: **0.570**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.5833$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.219\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5417\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5417\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.219\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (4.5417\ \text{kipft/ft})) + (4 \times (-0.219\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.2955\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.5417\ \text{kipft/ft})) + (3 \times (-0.219\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (4.5417\ \text{kipft/ft})) + (2 \times (-0.219\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = 0.32774\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (4.5417\ \text{kipft/ft})) + ((-0.219\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 1.159\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.2955\ \text{ft})}{2}$$

$$p_a = 0.39716\ \text{kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.32774 \text{ kip/ft}^2)}{(0.39716 \text{ kip/ft}^2)}$$ $$Ratio = 0.82519$$	Status: **PASS** Ratio: **0.830**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150 \text{ psf/ft}) \times (7.75 \text{ ft})$$ $$p_s = 1.1625 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(1.159 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$ $$Ratio = 0.99701$$	Status: **PASS** Ratio: **1.000**
	Considering z-direction: $H_o = 0.11267 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.389 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + (3\, H_o\, L_e^2)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.389 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (0.11267 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (0.389 \text{ kipft/ft})) + (4 \times (0.11267 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$ $$a = 5.5538 \text{ ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (0.389 \text{ kipft/ft})) + (3 \times (0.11267 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.389 \text{ kipft/ft})) + (2 \times (0.11267 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$ $$p = 0.11737 \text{ kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (0.389 \text{ kipft/ft})) + ((0.11267 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$ $$s = 0.2591 \text{ kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150 \text{ psf/ft}) \times \frac{(5.5538 \text{ ft})}{2}$$ $$p_a = 0.41653 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.11737 \text{ kip/ft}^2)}{(0.41653 \text{ kip/ft}^2)}$$	

$$Ratio = 0.28178$$

Status: **PASS**
Ratio: **0.280**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

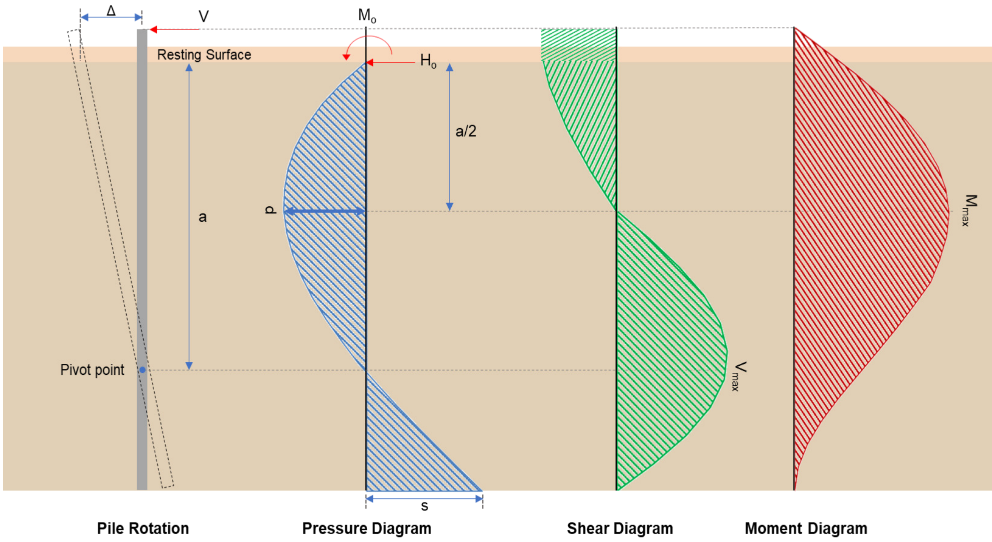
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.2591\ \mathrm{kip/ft^2})}{(1.1625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.22288$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.106\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.36867\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.302\ \mathrm{kipft}) + ((-1.106\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 7.7673\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.7673\ \mathrm{kipft/ft})}{(-0.36867\ \mathrm{kip/ft})}$$

$$E = 21.069\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.7673 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.36867 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (7.7673 \text{ kipft/ft})) + (4 \times (-0.36867 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2939 \text{ ft}$$

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

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

$$V_{max} = ((-0.36867 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.069 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.2939 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.069 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.2939 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.0538 \text{ kip}$$

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

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

$$M_{max} = ((-0.36867 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(21.069 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.2939 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (21.069 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.2939 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.069 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.2939 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 22.676 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.524 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.17467 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.817 \text{ kipft}) + ((0.524 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.60567 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.60567 \text{ kipft/ft})}{(0.17467 \text{ kip/ft})}$$

$$E = 3.4676 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.60567 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (0.17467 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (0.60567 \text{ kipft/ft})) + (4 \times (0.17467 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5531 \text{ ft}$$

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

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

$$V_{max} = ((0.17467\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5531\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5531\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.76458\ \text{kip}$$

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

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

$$M_{max} = ((0.17467\ \text{kip/ft}) \times (36\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(3.4676\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.6011\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.413\ \text{kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.985\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.985\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

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. 10⌀: 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

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

$$Ratio = \frac{(12.413\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0098994$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 12.413 \text{ kip} \rightarrow 12413 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(12413 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.545 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.545 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.545 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.545 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.565 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.0538 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.0538 \text{ kip})}{(74.565 \text{ kip})}$$

$$Ratio = 0.081189$$

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

Considering z-direction:

$V_{max} = 0.76458 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.76458 \text{ kip})}{(74.565 \text{ kip})}$$

$$Ratio = 0.010254$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - 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:

$M_{max} = 22.676 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(22.676 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.36559$$

Status: **PASS**
Ratio: **0.370**

Considering z-direction:

$M_{max} = 2.6011 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(2.6011 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.041935$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

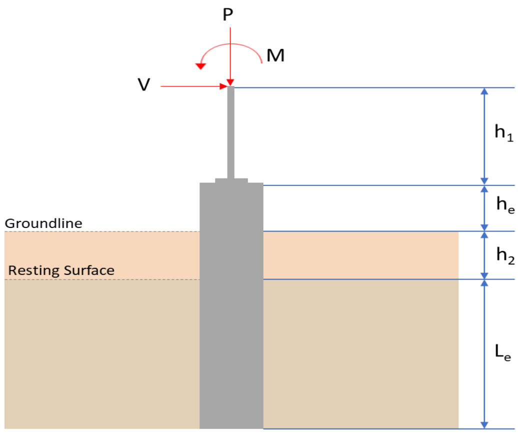
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 7.75 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.109	12.413
V_x (kip)	-0.657	-1.106
V_z (kip)	-0.338	-0.524
M_x (kipft)	-1.167	-1.817
M_z (kipft)	13.625	23.302

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,

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

$$H_o = \frac{(-0.657 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.219 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.625 \text{ kipft}) + ((-0.657 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 4.5417 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.4684 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.338 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.11267 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.167 \text{ kipft}) + ((-0.338 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.389 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.7161 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.4684 \text{ ft}), (2.7161 \text{ ft})]$$

$$L_{e,req} = 7.468 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.468 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.96361$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(8.109 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1472 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.1472 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.57359$$

Status: **PASS**
Ratio: **0.570**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.5833$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.219 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5417 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5417 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.219 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (4.5417 \text{ kipft/ft})) + (4 \times (-0.219 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2955 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.5417 \text{ kipft/ft})) + (3 \times (-0.219 \text{ kip/ft}) \times (7.75 \text{ ft}))]^{\,2}}{(7.75 \text{ ft})^2 \times [(3 \times (4.5417 \text{ kipft/ft})) + (2 \times (-0.219 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.32774 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (4.5417 \text{ kipft/ft})) + ((-0.219 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.159 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2955 \text{ ft})}{2}$$

$$p_a = 0.39716 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.32774\ \text{kip/ft}^2)}{(0.39716\ \text{kip/ft}^2)}$$

$$Ratio = 0.82519$$

Status: **PASS**
Ratio: **0.830**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.159\ \text{kip/ft}^2)}{(1.1625\ \text{kip/ft}^2)}$$

$$Ratio = 0.99701$$

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

Considering z-direction:

$H_o = -0.11267\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.389\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.389\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.11267\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.389\ \text{kipft/ft})) + (4 \times (-0.11267\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5538\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.389\ \text{kipft/ft})) + (3 \times (-0.11267\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (0.389\ \text{kipft/ft})) + (2 \times (-0.11267\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = -0.03829\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.389\ \text{kipft/ft})) + ((-0.11267\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = -0.014934\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.5538\ \text{ft})}{2}$$

$$p_a = 0.41653\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.03829\ \text{kip/ft}^2)}{(0.41653\ \text{kip/ft}^2)}$$

$$Ratio = -0.091926$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

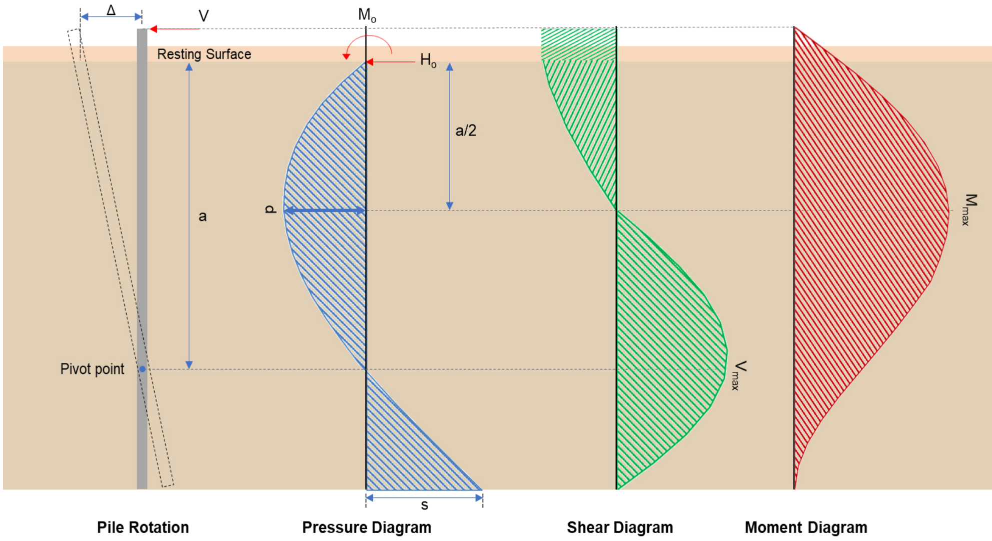
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.014934\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.012846$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.106\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.36867\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.302\ \mathrm{kipft}) + ((-1.106\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 7.7673\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.7673\ \mathrm{kipft/ft})}{(-0.36867\ \mathrm{kip/ft})}$$

$$E = 21.069\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.7673\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.36867\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (7.7673\ \text{kipft/ft})) + (4 \times (-0.36867\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.2939\ \text{ft}$$

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

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

$$V_{max} = ((-0.36867\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.069\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.2939\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.069\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.2939\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.0538\ \text{kip}$$

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

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

$$M_{max} = ((-0.36867\ \text{kip/ft}) \times (36\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(21.069\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.2939\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (21.069\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.2939\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.069\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.2939\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 22.676\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.524\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.17467\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.817\ \text{kipft}) + ((-0.524\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.60567\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.60567\ \text{kipft/ft})}{(-0.17467\ \text{kip/ft})}$$

$$E = 3.4676\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.60567\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.17467\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.60567\ \text{kipft/ft})) + (4 \times (-0.17467\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5531\ \text{ft}$$

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

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

$$V_{max} = ((-0.17467\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5531\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5531\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.76458\ \text{kip}$$

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

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

$$M_{max} = ((-0.17467\ \text{kip/ft}) \times (36\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(3.4676\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4676\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5531\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.6011\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.413\ \text{kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.985\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.985\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

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,

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

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

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

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,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.413 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.0098994$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 12.413 \text{ kip} \rightarrow 12413 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(12413 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.545 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.545 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.545 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((76.545 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.565 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.0538 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(6.0538\ \text{kip})}{(74.565\ \text{kip})}$$ $$Ratio = 0.081189$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $V_{max} = 0.76458\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.76458\ \text{kip})}{(74.565\ \text{kip})}$$ $$Ratio = 0.010254$$	Status: **PASS** Ratio: **0.010**
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:** $M_{max} = 22.676\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(22.676\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.36559$$	Status: **PASS** Ratio: **0.370**
	Considering z-direction: $M_{max} = 2.6011\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(2.6011 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.041935$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

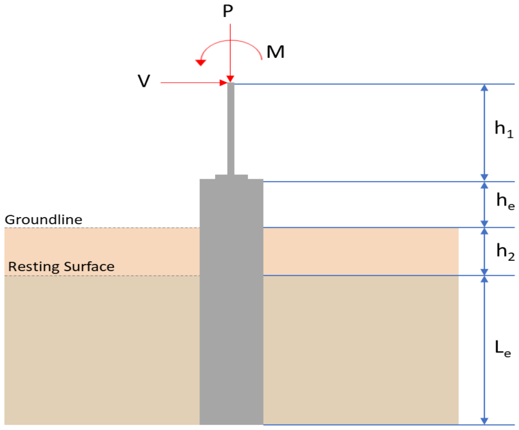
SkyCiv Foundation Design

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
$L = 8.25 \text{ ft}$ - 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)	10.882	16.732
V_x (kip)	-0.864	-1.448
V_z (kip)	-0.040	-0.064
M_x (kipft)	-0.142	-0.228
M_z (kipft)	16.562	28.101

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,

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

$$H_o = \frac{(-0.864 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.288 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.562\ \text{kipft}) + ((-0.864\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.5207\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.8354\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.04\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.013333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.142\ \text{kipft}) + ((-0.04\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.047333\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.5821\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.8354\ \text{ft}), (1.5821\ \text{ft})]$$

$$L_{e,req} = 7.835\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.835\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.9497$$

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

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

$$q = \frac{(10.882\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.5395\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.5395\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.76974$$

Status: **PASS**
Ratio: **0.770**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.288\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.5207\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.5207\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (5.5207\ \mathrm{kipft/ft})) + (4 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6533\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.5207\ \mathrm{kipft/ft})) + (3 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (5.5207\ \mathrm{kipft/ft})) + (2 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.32775\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.5207\ \mathrm{kipft/ft})) + ((-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

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

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6533\ \mathrm{ft})}{2}$$

$$p_a = 0.424\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.32775\ \text{kip/ft}^2\right)}{\left(0.424\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.773$$

Status: **PASS**
Ratio: **0.770**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.25\ \text{ft})$$

$$p_s = 1.2375\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.96965$$

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

Considering z-direction:

$H_o = -0.013333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.047333\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.047333\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.013333\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.047333\ \text{kipft/ft})) + (4 \times (-0.013333\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9178\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.047333\ \text{kipft/ft})) + (3 \times (-0.013333\ \text{kip/ft}) \times (8.25\ \text{ft}))]^{\ 2}}{(8.25\ \text{ft})^2 \times [(3 \times (0.047333\ \text{kipft/ft})) + (2 \times (-0.013333\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = -0.0043906\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.047333\ \text{kipft/ft})) + ((-0.013333\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = -0.0021233\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.9178\ \text{ft})}{2}$$

$$p_a = 0.44384\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0043906\ \text{kip/ft}^2\right)}{\left(0.44384\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.0098924$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.25\ \text{ft})$$

$$p_s = 1.2375\ \text{kip/ft}^2$$

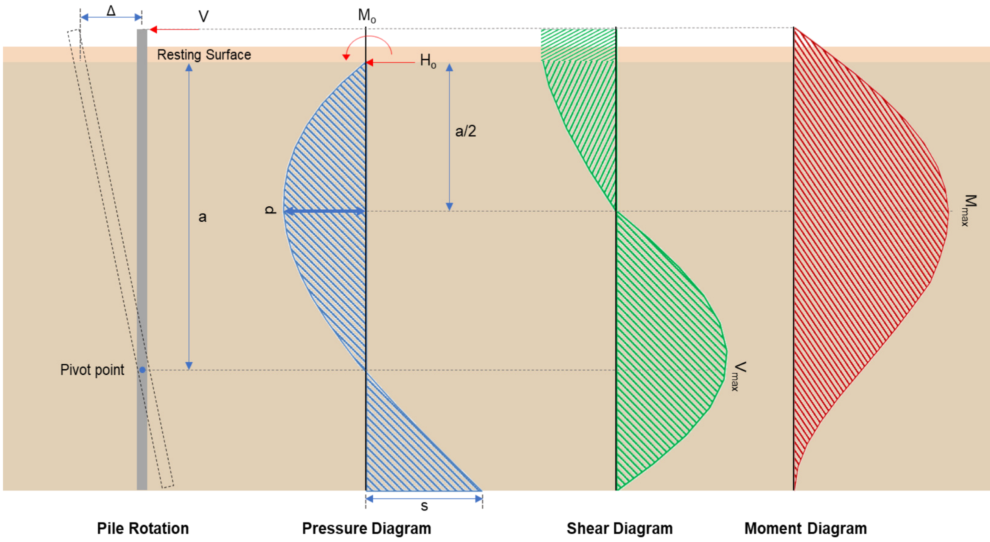
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0021233\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.0017158$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.448\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.48267\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.101\ \text{kipft}) + ((-1.448\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.367\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.367\ \text{kipft/ft})}{(-0.48267\ \text{kip/ft})}$$

$$E = 19.407\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.367\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.48267\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (9.367\ \mathrm{kipft/ft})) + (4 \times (-0.48267\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6518\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.48267\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.407\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.6518\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.407\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.6518\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.9851\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.48267\ \mathrm{kip/ft}) \times (36\ \mathrm{in}) \times (8.25\ \mathrm{ft})) \times \left[\left(\frac{(19.407\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + \frac{(5.6518\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (19.407\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.6518\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.407\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.6518\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 27.725\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.064\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.021333\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.228\ \mathrm{kipft}) + ((-0.064\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.076\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.076\ \mathrm{kipft/ft})}{(-0.021333\ \mathrm{kip/ft})}$$

$$E = 3.5625\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.076\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.021333\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.076\ \mathrm{kipft/ft})) + (4 \times (-0.021333\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.9172\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.021333\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5625\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9172\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5625\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9172\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.09164\ \text{kip}$$

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

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

$$M_{max} = ((-0.021333\ \text{kip/ft}) \times (36\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(3.5625\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9172\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.5625\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9172\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5625\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9172\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.33101\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.732\ \text{kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.85\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.85\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

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 *25.7.2.1*	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) 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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(16.732\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.013344$$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD)	
	Parameters:	
22.5.2.2	$b_w = 36\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$	
22.5.5.1.1	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.732 \text{ kip} \rightarrow 16732 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(16732 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.278 \text{ kip}$$

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

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

$$V_c = Min\left[(186.09 \text{ kip}), (77.278 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 77.278 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((77.278 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 75.042 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.9851 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.9851 \text{ kip})}{(75.042 \text{ kip})}$$

$$Ratio = 0.093082$$

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

Considering z-direction:

$V_{max} = 0.09164$ kip - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.09164 \text{ kip})}{(75.042 \text{ kip})}$$

$$Ratio = 0.0012212$$

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:

$M_{max} = 27.725$ kipft - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(27.725 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.44698$$

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

Considering z-direction:

$M_{max} = 0.33101$ kipft - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.33101 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0053366$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

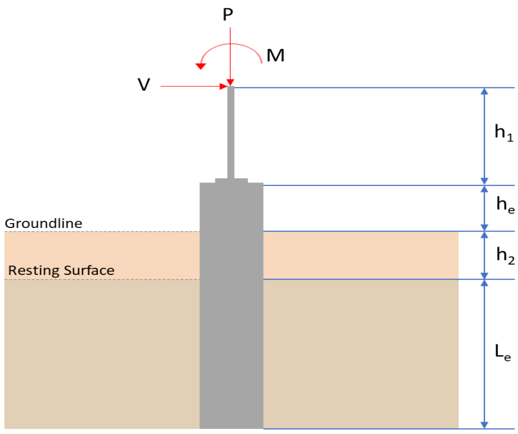
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.25\ \mathrm{ft}$ - 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)	10.882	16.732
V_x (kip)	-0.864	-1.448
V_z (kip)	0.040	0.064
M_x (kipft)	0.142	0.228
M_z (kipft)	16.562	28.101

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,

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

$$H_o = \frac{(-0.864\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.288\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.562\ \text{kipft}) + ((-0.864\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.5207\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.8354\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.04\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.013333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.142\ \text{kipft}) + ((0.04\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.047333\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.0419\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.8354\ \text{ft}), (2.0419\ \text{ft})]$$

$$L_{e,req} = 7.835\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.835\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.9497$$

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

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

$$q = \frac{(10.882\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.5395\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.5395\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.76974$$

Status: **PASS**
Ratio: **0.770**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.288\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.5207\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.5207\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (5.5207\ \mathrm{kipft/ft})) + (4 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6533\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.5207\ \mathrm{kipft/ft})) + (3 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (5.5207\ \mathrm{kipft/ft})) + (2 \times (-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.32775\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.5207\ \mathrm{kipft/ft})) + ((-0.288\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

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

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6533\ \mathrm{ft})}{2}$$

$$p_a = 0.424\ \mathrm{kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.32775 \text{ kip/ft}^2\right)}{\left(0.424 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.773$$	Status: **PASS** Ratio: **0.770**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$ $$p_s = 1.2375 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.2 \text{ kip/ft}^2\right)}{\left(1.2375 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.96965$$	Status: **PASS** Ratio: **0.970**

Considering z-direction:

$H_o = 0.013333 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.047333 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.047333 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (0.013333 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.047333 \text{ kipft/ft})) + (4 \times (0.013333 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.9178 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.047333 \text{ kipft/ft})) + (3 \times (0.013333 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (0.047333 \text{ kipft/ft})) + (2 \times (0.013333 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.012895 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.047333 \text{ kipft/ft})) + ((0.013333 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 0.028341 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.9178 \text{ ft})}{2}$$

$$p_a = 0.44384 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.012895 \text{ kip/ft}^2\right)}{\left(0.44384 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.029053$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.25\ \text{ft})$$

$$p_s = 1.2375\ \text{kip/ft}^2$$

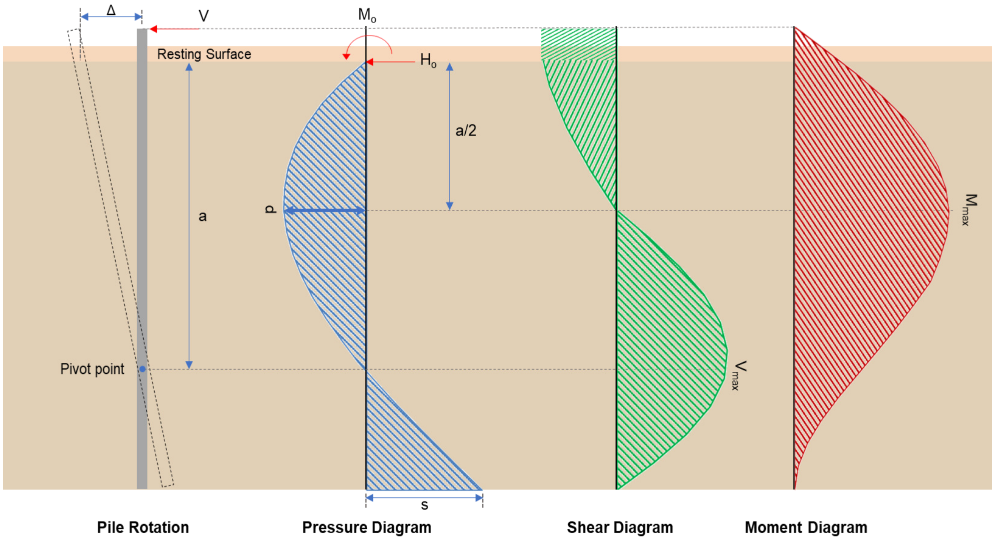
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.028341\ \text{kip/ft}^2)}{(1.2375\ \text{kip/ft}^2)}$$

$$Ratio = 0.022902$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.448\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.48267\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.101\ \text{kipft}) + ((-1.448\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.367\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.367\ \text{kipft/ft})}{(-0.48267\ \text{kip/ft})}$$

$$E = 19.407\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.367\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.48267\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (9.367\ \text{kipft/ft})) + (4 \times (-0.48267\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6518\ \text{ft}$$

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

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

$$V_{max} = ((-0.48267\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.407\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6518\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.407\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6518\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.9851\ \text{kip}$$

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

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

$$M_{max} = ((-0.48267\ \text{kip/ft}) \times (36\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(19.407\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6518\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (19.407\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6518\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.407\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6518\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 27.725\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.064\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.021333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.228\ \text{kipft}) + ((0.064\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.076\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.076\ \text{kipft/ft})}{(0.021333\ \text{kip/ft})}$$

$$E = 3.5625\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.076\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.021333\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.076\ \text{kipft/ft})) + (4 \times (0.021333\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9172\ \text{ft}$$

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

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

$$V_{max} = ((0.021333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5625 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.9172 \text{ ft})}{(8.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5625 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.9172 \text{ ft})}{(8.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.09164 \text{ kip}$$

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

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

$$M_{max} = ((0.021333 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[\left(\frac{(3.5625 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.9172 \text{ ft})}{2 \times (8.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.5625 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.9172 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5625 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.9172 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.33101 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.732 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -36.85 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.85 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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 *25.7.2.1*	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) 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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.85\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(16.732\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.013344$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 *22.5.5.1.3* *22.5.5.1.1*	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.732\ \text{kip} \rightarrow 16732\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(16732\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 77.278\ \text{kip}$$

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

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

$$V_c = Min\left[(186.09\ \text{kip}), (77.278\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 77.278\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((77.278\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 75.042\ \text{kip}$$

Considering x-direction:

$V_{max} = 6.9851\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.9851 \text{ kip})}{(75.042 \text{ kip})}$$

$$Ratio = 0.093082$$

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

Considering z-direction:

$V_{max} = 0.09164$ kip - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.09164 \text{ kip})}{(75.042 \text{ kip})}$$

$$Ratio = 0.0012212$$

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

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:

$M_{max} = 27.725$ kipft - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(27.725 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.44698$$

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

Considering z-direction:

$M_{max} = 0.33101$ kipft - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.33101 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0053366$$	Status: **PASS** Ratio: **0.010**