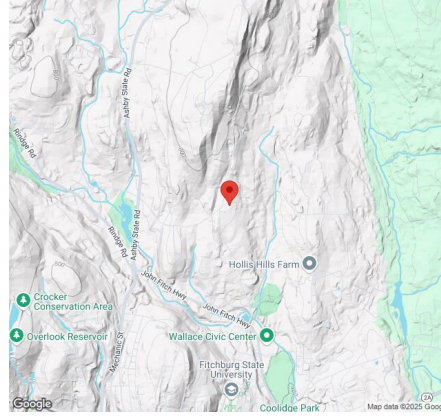


Site Details:



Site Address: 453 Fisher Rd, Fitchburg, MA 01420, USA

Array Specification

Duty Classification:	HD
Module Width:	44.60 in
Module Length:	69.40in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Winter Tilt Angle:	50
Front Edge Clearance:	5
Total Array Height at Tilt:	19.40 ft
Total Frame Length:	68.75 ft
Module Info/Notes:	SEG 430
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	70.40 ft
Rail Length:	225.50 in
Rail Spacing:	2.93 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	12.20 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.50 ft Pile 2: 7.00 ft Pile 3: 7.00 ft Pile 4: 6.50 ft
Foundation Volume:	16.000 y ³

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	453 Fisher Rd, Fitchburg, MA 01420, USA
Wind Speed:	107 mph

Snow Load:

60 psf

Design Disclaimer

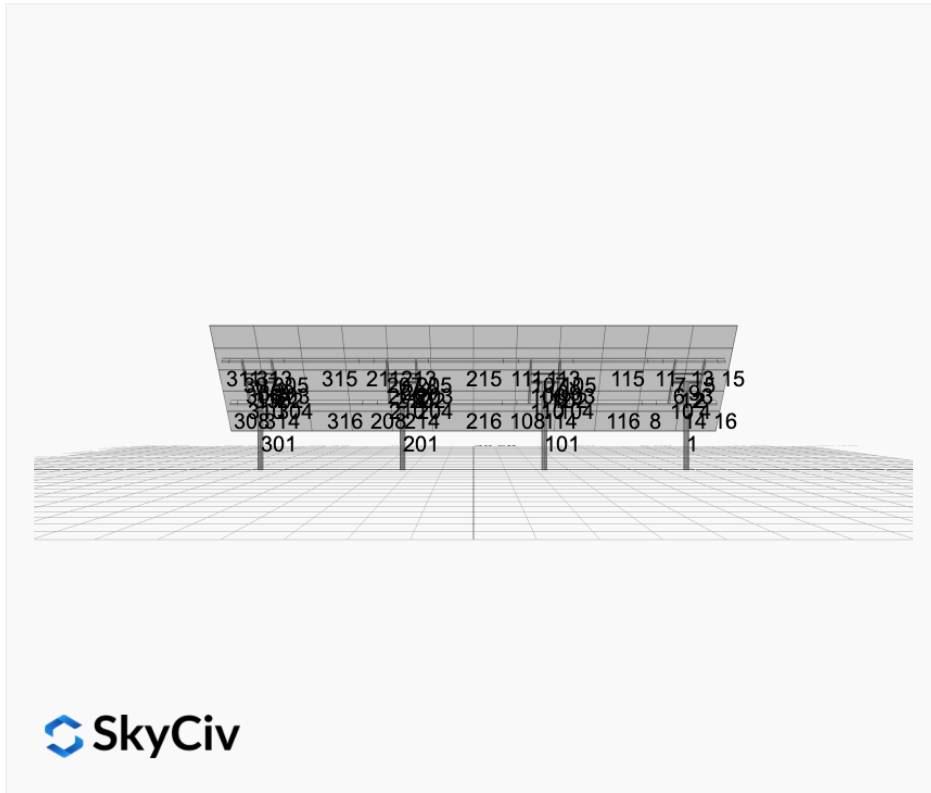
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

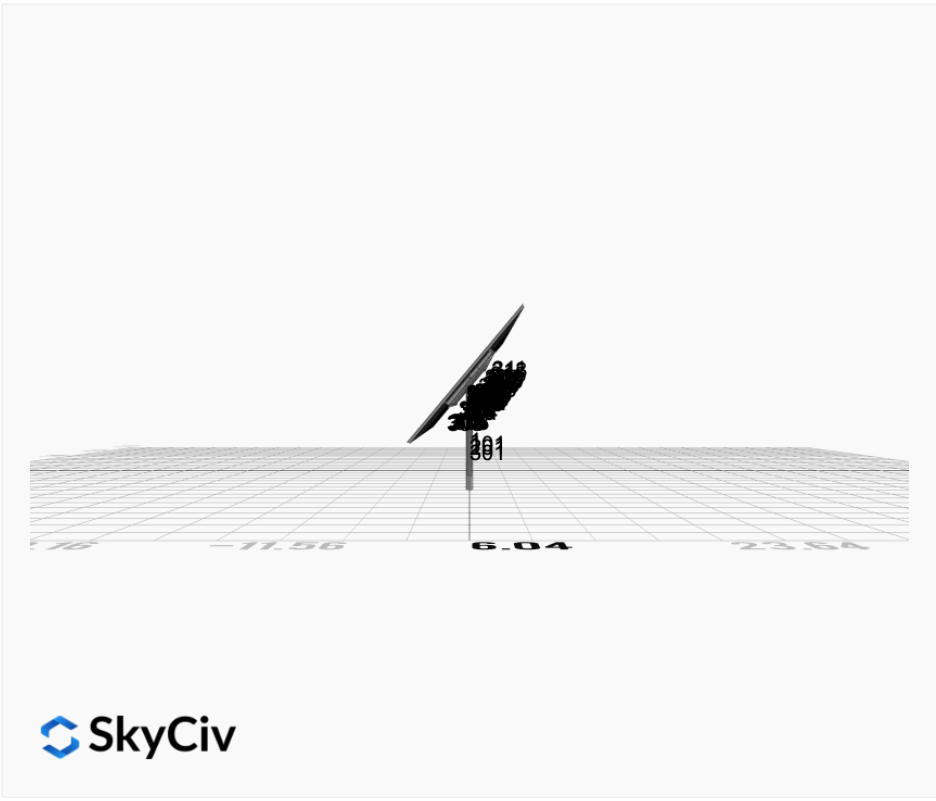
AutoDesigner Input

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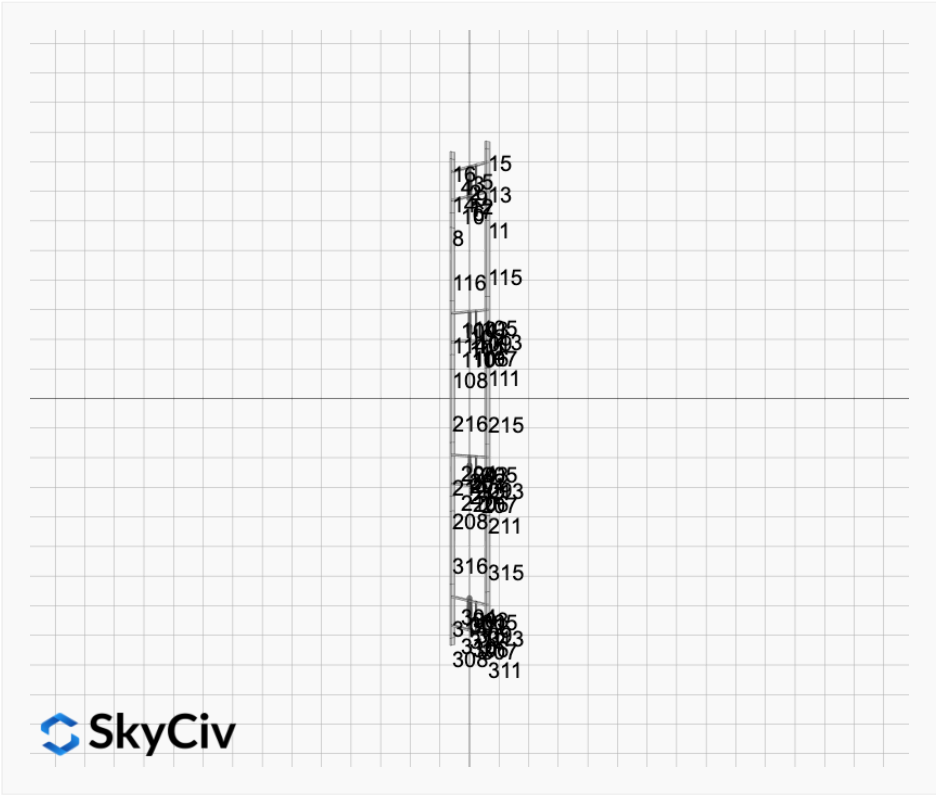
Design Notes:

- 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)

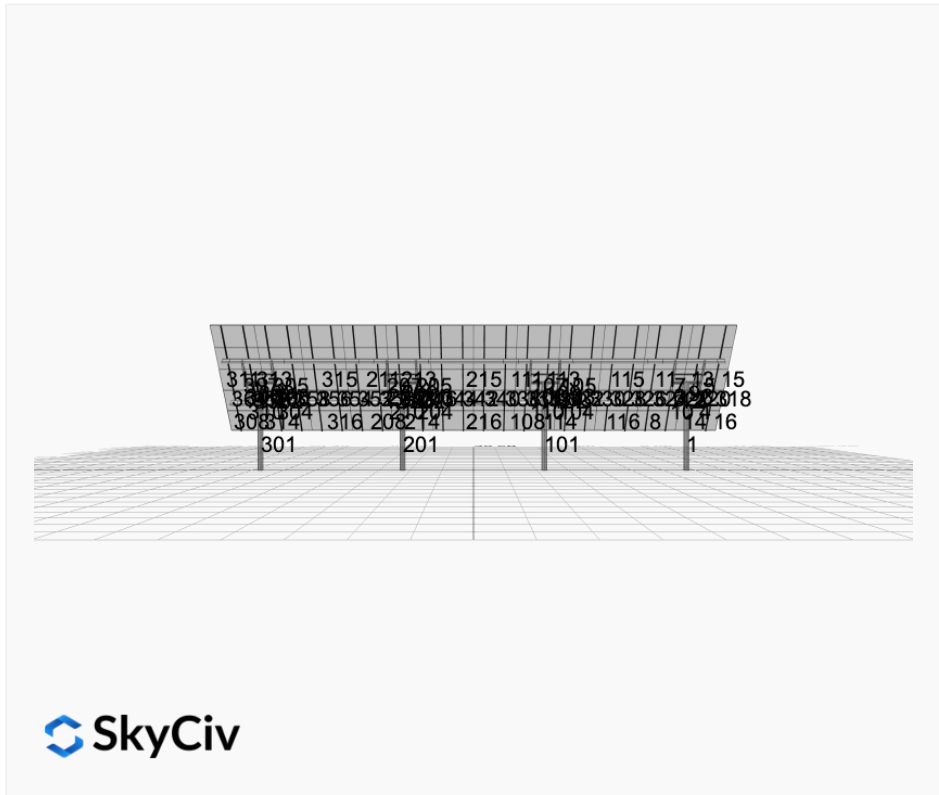
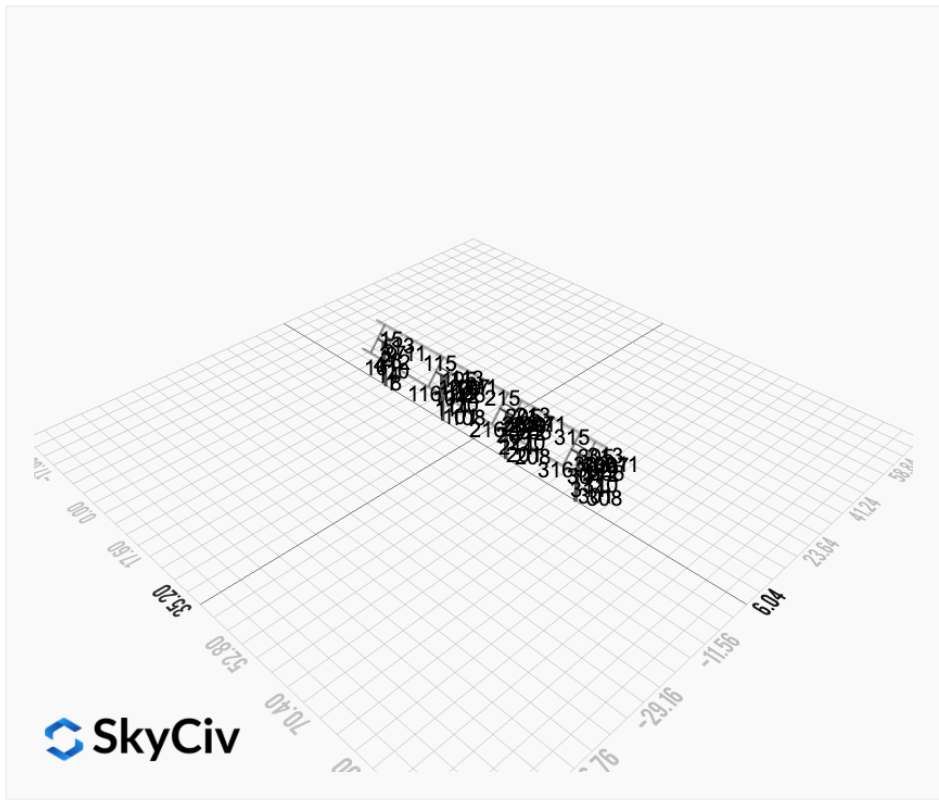




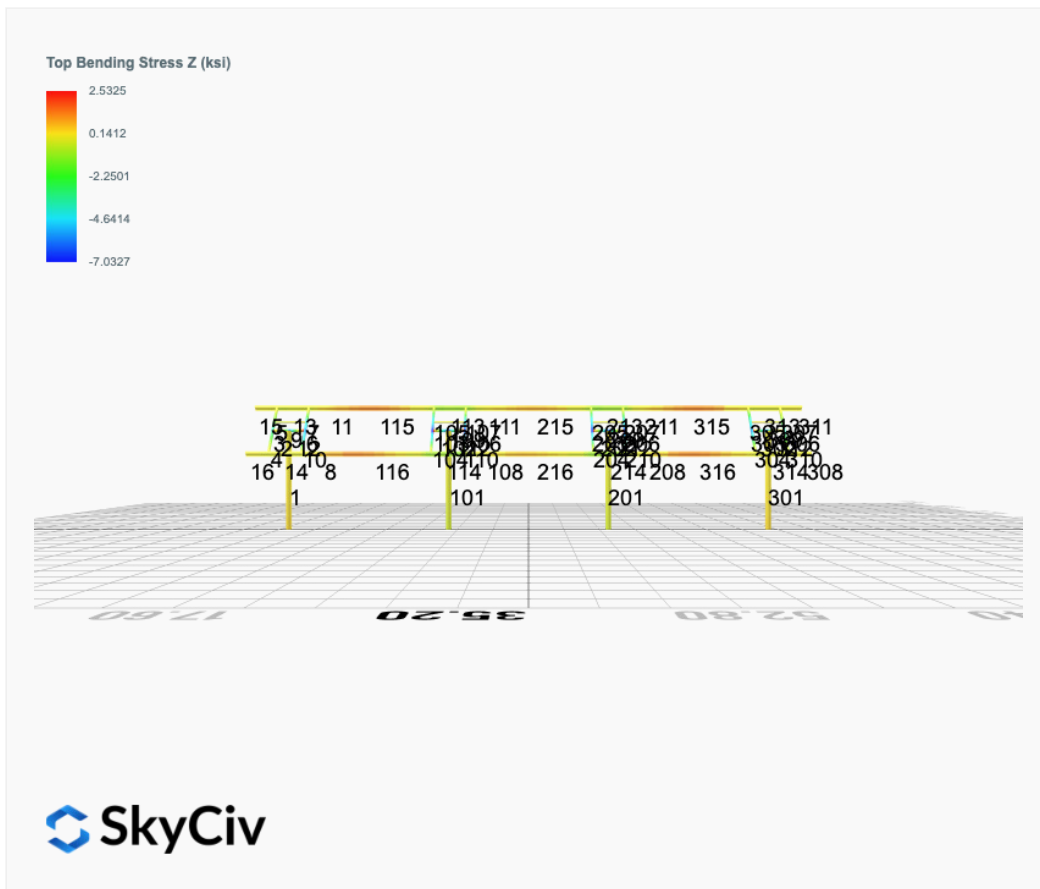
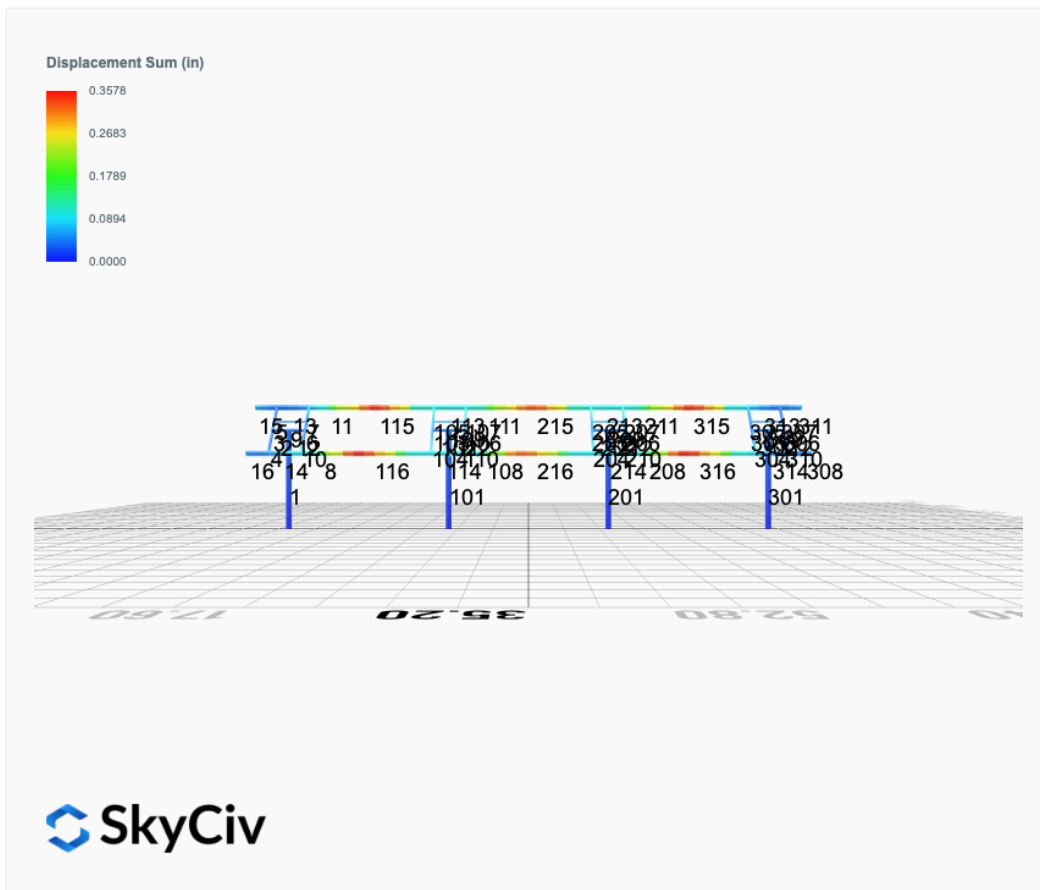
 SkyCiv



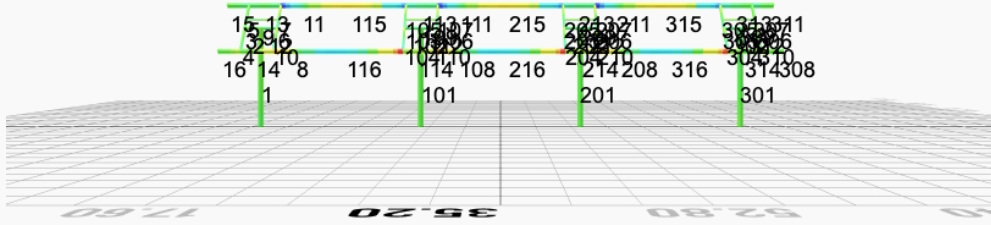
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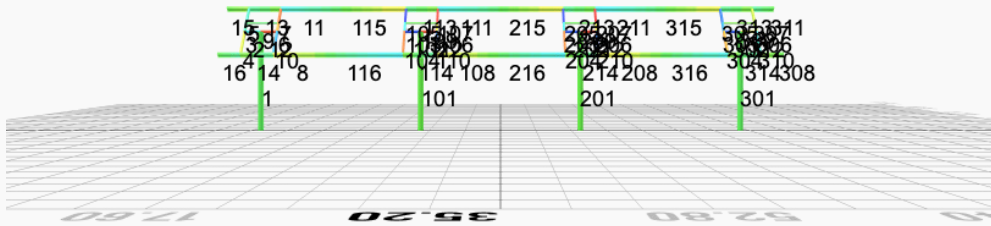
FEM Results (Envelope Worst Case for each member)



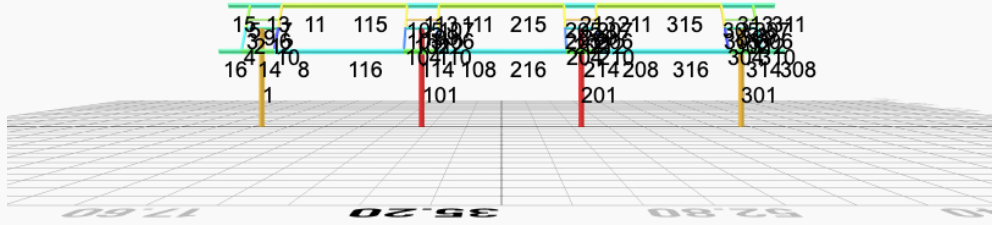
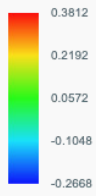
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 2. D + L	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 3. D + (S or Lr or R)	0.0912	4.3748	0.2448	0.9111	-0.3377	-1.0253
ULS: 3. D + (S or Lr or R)	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0776	3.8055	0.2082	0.7749	-0.2872	-0.8697
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 5b. D + 0.7E	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0776	3.8055	0.2082	0.7749	-0.2872	-0.8697
ULS: 8. 0.6D + 0.7E	0.0221	1.2585	0.0591	0.2198	-0.0814	-0.2417
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1439	3.8710	0.3398	1.2169	-1.3854	26.7710
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2128	0.3267	-0.1376	-0.4651	1.0881	-26.9584
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5579	5.1356	0.3892	1.4129	-1.2245	19.5107
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0776	3.8055	0.2082	0.7749	-0.2872	-0.8697
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7096	2.4774	0.0311	0.1514	0.6306	-20.7864
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0776	3.8055	0.2082	0.7749	-0.2872	-0.8697
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5987	3.4276	0.2794	1.0043	-1.0729	19.9775
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6688	0.7694	-0.0786	-0.2572	0.7822	-20.3195
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0368	2.0976	0.0985	0.3663	-0.1356	-0.4028
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1586	3.0320	0.3004	1.0704	-1.3311	26.9321
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0221	1.2585	0.0591	0.2198	-0.0814	-0.2417
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1981	-0.5123	-0.1770	-0.6116	1.1423	-26.7973
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0221	1.2585	0.0591	0.2198	-0.0814	-0.2417

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.6396
Shear X	-3.7020
Shear Z	0.5984
Moment X	2.1490
Moment Y (Twist)	2.3704
Moment Z	45.6885

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.1356
Shear X	-2.2128
Shear Z	0.3892
Moment X	1.4129
Moment Y (Twist)	1.3854
Moment Z	26.9584

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	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 2. D + L	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 3. D + (S or Lr or R)	-0.0912	5.9234	-0.0082	-0.0325	0.0362	1.0916
ULS: 3. D + (S or Lr or R)	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0776	5.1229	-0.0070	-0.0276	0.0308	0.9304

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 5b. D + 0.7E	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0776	5.1229	-0.0070	-0.0276	0.0308	0.9304
ULS: 8. 0.6D + 0.7E	-0.0221	1.6329	-0.0020	-0.0079	0.0088	0.2681
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0425	5.3000	0.0269	0.0902	-0.1933	37.3474
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9736	0.1406	-0.0306	-0.1059	0.2061	-35.4701
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3319	7.0567	0.0157	0.0499	-0.1252	28.6059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0776	5.1229	-0.0070	-0.0276	0.0308	0.9304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1801	3.1872	-0.0275	-0.0972	0.1744	-26.0073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0776	5.1229	-0.0070	-0.0276	0.0308	0.9304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2910	4.6554	0.0194	0.0644	-0.1413	28.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2210	0.7858	-0.0238	-0.0827	0.1582	-26.4909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0368	2.7216	-0.0033	-0.0131	0.0147	0.4468
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0278	4.2114	0.0283	0.0954	-0.1992	37.1686
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0221	1.6329	-0.0020	-0.0079	0.0088	0.2681
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.9883	-0.9481	-0.0293	-0.1006	0.2002	-35.6488
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0221	1.6329	-0.0020	-0.0079	0.0088	0.2681

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.5364
Shear X	-5.0762
Shear Z	-0.0546
Moment X	-0.1891
Moment Y (Twist)	0.3626
Moment Z	63.4360

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.0567
Shear X	-3.0425
Shear Z	-0.0306
Moment X	-0.1059
Moment Y (Twist)	0.2061
Moment Z	37.3474

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	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 2. D + L	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 3. D + (S or Lr or R)	-0.0912	5.9234	0.0082	0.0324	-0.0360	1.0917
ULS: 3. D + (S or Lr or R)	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0776	5.1229	0.0070	0.0275	-0.0307	0.9304
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 5b. D + 0.7E	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0776	5.1229	0.0070	0.0275	-0.0307	0.9304
ULS: 8. 0.6D + 0.7E	-0.0221	1.6329	0.0020	0.0079	-0.0088	0.2681
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0425	5.3000	-0.0269	-0.0902	0.1933	37.3474
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9736	0.1406	0.0306	0.1059	-0.2061	-35.4701
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3319	7.0567	-0.0157	-0.0500	0.1253	28.6059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0776	5.1229	0.0070	0.0275	-0.0307	0.9304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1801	3.1872	0.0275	0.0971	-0.1743	-26.0073
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0776	5.1229	0.0070	0.0275	-0.0307	0.9304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2910	4.6554	-0.0194	-0.0644	0.1413	28.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2210	0.7858	0.0238	0.0827	-0.1582	-26.4909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0368	2.7216	0.0033	0.0131	-0.0146	0.4468
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0278	4.2114	-0.0283	-0.0955	0.1992	37.1687
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0221	1.6329	0.0020	0.0079	-0.0088	0.2681
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.9883	-0.9481	0.0293	0.1006	-0.2002	-35.6488
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0221	1.6329	0.0020	0.0079	-0.0088	0.2681

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.5364
Shear X	-5.0763
Shear Z	0.0546
Moment X	0.1896
Moment Y (Twist)	0.3626
Moment Z	63.4362

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.0567
Shear X	-3.0425
Shear Z	0.0306
Moment X	0.1059
Moment Y (Twist)	0.2061
Moment Z	37.3474

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	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 2. D + L	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 3. D + (S or Lr or R)	0.0912	4.3748	-0.2448	-0.9113	0.3378	-1.0252
ULS: 3. D + (S or Lr or R)	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0776	3.8055	-0.2082	-0.7751	0.2873	-0.8696
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 5b. D + 0.7E	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0776	3.8055	-0.2082	-0.7751	0.2873	-0.8696
ULS: 8. 0.6D + 0.7E	0.0221	1.2585	-0.0591	-0.2198	0.0814	-0.2417
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1439	3.8710	-0.3398	-1.2170	1.3854	26.7710
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2128	0.3267	0.1376	0.4650	-1.0881	-26.9584
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5579	5.1356	-0.3892	-1.4131	1.2246	19.5108
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0776	3.8055	-0.2082	-0.7751	0.2873	-0.8696
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7096	2.4773	-0.0311	-0.1516	-0.6305	-20.7863
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0776	3.8055	-0.2082	-0.7751	0.2873	-0.8696
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5987	3.4276	-0.2794	-1.0043	1.0730	19.9775
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6688	0.7694	0.0786	0.2572	-0.7821	-20.3195
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0368	2.0976	-0.0985	-0.3663	0.1357	-0.4028

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1586	3.0320	-0.3004	-1.0704	1.3311	26.9321
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0221	1.2585	-0.0591	-0.2198	0.0814	-0.2417
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1981	-0.5123	0.1770	0.6115	-1.1423	-26.7973
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0221	1.2585	-0.0591	-0.2198	0.0814	-0.2417

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.6395
Shear X	-3.7020
Shear Z	-0.5984
Moment X	-2.1497
Moment Y (Twist)	2.3708
Moment Z	45.6892

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.1356
Shear X	-2.2128
Shear Z	-0.3892
Moment X	-1.4131
Moment Y (Twist)	1.3854
Moment Z	26.9584

Project Details

Design Code: AISC 360-16 LRFD
 Provision: LRFD
 Country: United States
 User Name: sales@mtsolar.us
 Project Name: MTSOLAR_IIG39F3A8C5L ExpB 50deg - V1Jb
 Unit System: imperial



Design Input Information

Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

Section Dimensions

ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
9	8in Pipe Sch 40	8.63	0.32					

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

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

Section Properties								
ID	Name	A (in ²)	J (in ⁴)	I_{y0} (in ⁴)	I_{z0} (in ⁴)	I_w (in ⁶)	S_{y0} (in ³)	S_{z0} (in ³)

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K _z L (ft)	K _y L (ft)	L _b (ft)	C _b	LS T	LS C	L D
1	9	25.6 2	25.6 2	12. 20	-	30 0	20 0	1
2	5	1.30	1.30	2.0 0	-	30 0	20 0	1
3	16	0.92	0.92	1.4 2	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.18,1.15,1.18,1.17,1.18,1.15,1.18,1.17,1.17,1.19,1.17,1.17,1.18,1.1 4,1.18,1.16,1.18,1.16,1.18	30 0	20 0	1
4	16	2.44	2.44	3.7 5	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.69,1.68,1.68,1.69,1.6 4,1.69,1.67,1.69,1.66,1.69	30 0	20 0	1
5	16	1.52	1.52	2.3 3	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.6 4,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
6	16	0.92	0.92	1.4 2	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.1 8,1.19,1.19,1.19,1.19,1.19	30 0	20 0	1
7	16	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.6 6,1.68,1.67,1.68,1.67,1.68	30 0	20 0	1
8	19	1.33	1.33	2.0 5	1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.24,1.2 4,1.24,1.24,1.24,1.24,1.24	30 0	20 0	1
9	2	2.60	2.60	4.0 0	-	30 0	20 0	1
10	16	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
11	19	1.33	1.33	2.0 5	1.28,1.28,1.28,1.28,1.28,1.28,1.34,1.28,1.44,1.28,1.35,1.28,1.40,1.28,1.31,1.28,1.15,1.28,1.34,1.28,1.4 9,1.28,1.35,1.28,1.39,1.28	30 0	20 0	1
12	5	1.30	1.30	2.0 0	-	30 0	20 0	1
13	19	4.88	4.00	7.5 0	1.26,1.26,1.26,1.26,1.26,1.26,1.17,1.26,1.29,1.26,1.17,1.26,1.24,1.26,1.20,1.26,3.01,1.26,1.17,1.26,1.3 3,1.26,1.18,1.26,1.23,1.26	30 0	20 0	1
14	19	4.88	4.00	7.5 0	1.38,1.39,1.38,1.40,1.39,1.38,1.47,1.39,1.58,1.39,1.48,1.38,1.54,1.38,1.45,1.40,1.36,1.40,1.46,1.38,1.6 3,1.38,1.48,1.38,1.53,1.38	30 0	20 0	1
15	19	2.10	2.10	1.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33	30 0	20 0	1
16	19	2.10	2.10	1.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33	30 0	20 0	1
101	9	25.6 2	25.6 2	12. 20	-	30 0	20 0	1
102	5	1.30	1.30	2.0 0	-	30 0	20 0	1
103	16	0.92	0.92	1.4 2	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.1 6,1.18,1.18,1.18,1.17,1.18	30 0	20 0	1
104	16	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
105	16	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.6 6,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
106	16	0.92	0.92	1.4 2	1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.1 7,1.18,1.18,1.19,1.18,1.19	30 0	20 0	1
107	16	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.6 6,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
108	19	1.33	1.33	2.0 5	2.19,2.20,2.19,2.20,2.19,2.19,2.09,2.20,2.05,2.20,2.08,2.19,2.07,2.19,2.10,2.20,2.20,2.20,2.09,2.19,1.9 3,2.19,2.08,2.19,2.07,2.19	30 0	20 0	1
109	2	2.60	2.60	4.0 0	-	30 0	20 0	1
110	16	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
111	19	1.33	1.33	2.0 5	2.08,2.08,2.08,2.08,2.09,2.09,1.63,2.08,1.36,2.08,1.60,2.08,1.44,2.08,1.85,2.08,1.47,2.08,1.67,2.08,1.3 2,2.08,1.58,2.09,1.47,2.09	30 0	20 0	1
112	5	1.30	1.30	2.0 0	-	30 0	20 0	1

314	19	4.88	4.00	0	4,1.38,1.48,1.38,1.53,1.38	0	0	1
315	19	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.11,1.08,1.09,1.08,1.10,1.08,1.08,1.08,1.11,1.08,1.09,1.08,1.12,1.08,1.09,1.08,1.10,1.08	30.0	20.0	1
316	19	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.08	30.0	20.0	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	169.75	83.29	83.29	113.39	113.39
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	26.71	6.12	40.24	43.62
14	133.20	85.85	31.11	6.12	40.24	43.62
15	133.20	121.82	32.87	6.12	40.24	43.62
16	133.20	121.82	32.87	6.12	40.24	43.62
101	377.97	169.75	83.29	83.29	113.39	113.39
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.68	6.12	40.24	43.62
114	133.20	85.85	23.77	6.12	40.24	43.62
115	133.20	69.16	16.51	6.12	40.24	43.62
116	133.20	69.16	17.49	6.12	40.24	43.62
201	377.97	169.75	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62

212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.68	6.12	40.24	43.62
214	133.20	85.85	23.76	6.12	40.24	43.62
215	133.20	69.16	16.84	6.12	40.24	43.62
216	133.20	69.16	17.60	6.12	40.24	43.62
301	377.97	169.75	83.29	83.29	113.39	113.39
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	121.82	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	121.82	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	26.70	6.12	40.24	43.62
314	133.20	85.85	31.06	6.12	40.24	43.62
315	133.20	69.16	16.71	6.12	40.24	43.62
316	133.20	69.16	16.60	6.12	40.24	43.62

Design Ratio

Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.045	0.549	0.062	0.033	0.005	0.588	#13	0.523	Not Required	Pass
2	0.002	0.137	0.105	0.038	0.024	0.211	#13	0.053	Not Required	Pass
3	0.006	0.282	0.028	0.026	0.005	0.291	#13	0.045	Not Required	Pass
4	0.005	0.284	0.072	0.029	0.017	0.352	#13	0.080	Not Required	Pass
5	0.005	0.175	0.033	0.028	0.009	0.178	#13	0.074	Not Required	Pass
6	0.013	0.528	0.128	0.055	0.036	0.606	#13	0.045	Not Required	Pass
7	0.014	0.328	0.209	0.052	0.050	0.351	#13	0.074	Not Required	Pass
8	0.006	0.115	0.191	0.031	0.021	0.202	#23	0.095	Not Required	Pass
9	0.006	0.057	0.086	0.005	0.005	0.114	#13	0.204	Not Required	Pass
10	0.015	0.486	0.200	0.049	0.043	0.528	#21	0.080	Not Required	Pass
11	0.008	0.103	0.197	0.034	0.021	0.215	#23	0.095	Not Required	Pass
12	0.001	0.354	0.213	0.083	0.042	0.553	#13	0.053	Not Required	Pass
13	0.011	0.067	0.497	0.044	0.027	0.506	#21	0.286	Not Required	Pass
14	0.006	0.053	0.487	0.041	0.027	0.496	#23	0.190	Not Required	Pass
15	0.000	0.004	0.012	0.006	0.003	0.015	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.012	0.006	0.003	0.015	#21	Not Required	Not Required	Pass
101	0.062	0.762	0.006	0.045	0.000	0.791	#13	0.523	Not Required	Pass
102	0.004	0.344	0.224	0.085	0.041	0.533	#13	0.035	Not Required	Pass
103	0.013	0.538	0.080	0.053	0.012	0.589	#13	0.045	Not Required	Pass
104	0.013	0.568	0.215	0.057	0.046	0.662	#13	0.080	Not Required	Pass
105	0.013	0.333	0.224	0.053	0.056	0.367	#13	0.074	Not Required	Pass
106	0.013	0.574	0.079	0.058	0.012	0.615	#13	0.045	Not Required	Pass
107	0.013	0.357	0.210	0.057	0.053	0.389	#13	0.074	Not Required	Pass
108	0.007	0.043	0.181	0.035	0.021	0.211	#21	0.095	Not Required	Pass
109	0.018	0.040	0.048	0.001	0.000	0.093	#13	0.204	Not Required	Pass
110	0.013	0.574	0.200	0.057	0.043	0.617	#13	0.080	Not Required	Pass

110	0.013	0.374	0.200	0.037	0.043	0.047	#13	0.000	Not Required	Pass
111	0.008	0.069	0.187	0.035	0.021	0.209	#23	0.095	Not Required	Pass
112	0.004	0.350	0.240	0.085	0.045	0.567	#13	0.035	Not Required	Pass
113	0.011	0.130	0.517	0.046	0.027	0.621	#21	0.286	Not Required	Pass
114	0.010	0.178	0.511	0.050	0.027	0.648	#21	0.286	Not Required	Pass
115	0.014	0.303	0.271	0.036	0.021	0.537	#21	0.473	Not Required	Pass
116	0.006	0.283	0.268	0.040	0.021	0.516	#21	0.473	Not Required	Pass
201	0.062	0.762	0.006	0.045	0.000	0.791	#13	0.523	Not Required	Pass
202	0.004	0.350	0.240	0.085	0.045	0.567	#13	0.035	Not Required	Pass
203	0.013	0.574	0.079	0.058	0.012	0.615	#13	0.045	Not Required	Pass
204	0.013	0.574	0.200	0.057	0.043	0.647	#13	0.080	Not Required	Pass
205	0.013	0.357	0.210	0.057	0.053	0.389	#13	0.074	Not Required	Pass
206	0.013	0.538	0.080	0.053	0.012	0.589	#13	0.045	Not Required	Pass
207	0.013	0.333	0.224	0.053	0.056	0.367	#13	0.074	Not Required	Pass
208	0.006	0.071	0.209	0.040	0.021	0.226	#21	0.095	Not Required	Pass
209	0.018	0.040	0.048	0.001	0.000	0.093	#13	0.204	Not Required	Pass
210	0.013	0.568	0.215	0.057	0.046	0.662	#13	0.080	Not Required	Pass
211	0.008	0.095	0.214	0.036	0.021	0.223	#21	0.095	Not Required	Pass
212	0.004	0.344	0.224	0.085	0.041	0.533	#13	0.035	Not Required	Pass
213	0.011	0.130	0.517	0.046	0.027	0.621	#21	0.286	Not Required	Pass
214	0.010	0.178	0.511	0.050	0.027	0.648	#21	0.286	Not Required	Pass
215	0.014	0.242	0.272	0.035	0.021	0.471	#21	0.473	Not Required	Pass
216	0.007	0.186	0.267	0.035	0.021	0.428	#21	0.473	Not Required	Pass
301	0.045	0.549	0.062	0.033	0.005	0.588	#13	0.523	Not Required	Pass
302	0.001	0.354	0.213	0.083	0.042	0.553	#13	0.053	Not Required	Pass
303	0.013	0.528	0.128	0.055	0.036	0.606	#13	0.045	Not Required	Pass
304	0.015	0.486	0.200	0.049	0.043	0.528	#21	0.080	Not Required	Pass
305	0.014	0.328	0.209	0.052	0.050	0.351	#13	0.074	Not Required	Pass
306	0.006	0.282	0.028	0.026	0.005	0.291	#13	0.045	Not Required	Pass
307	0.005	0.175	0.033	0.028	0.009	0.178	#13	0.074	Not Required	Pass
308	0.000	0.004	0.012	0.006	0.003	0.015	#21	Not Required	Not Required	Pass
309	0.006	0.057	0.086	0.005	0.005	0.114	#13	0.204	Not Required	Pass
310	0.005	0.284	0.072	0.029	0.017	0.352	#13	0.120	Not Required	Pass
311	0.000	0.004	0.012	0.006	0.003	0.015	#21	Not Required	Not Required	Pass
312	0.002	0.137	0.105	0.038	0.024	0.211	#13	0.053	Not Required	Pass
313	0.011	0.067	0.496	0.044	0.027	0.506	#21	0.190	Not Required	Pass
314	0.006	0.053	0.488	0.041	0.027	0.496	#23	0.286	Not Required	Pass
315	0.014	0.306	0.272	0.034	0.021	0.542	#21	0.473	Not Required	Pass
316	0.006	0.303	0.266	0.031	0.021	0.525	#21	0.473	Not Required	Pass

Definitions

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

S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/compression)
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
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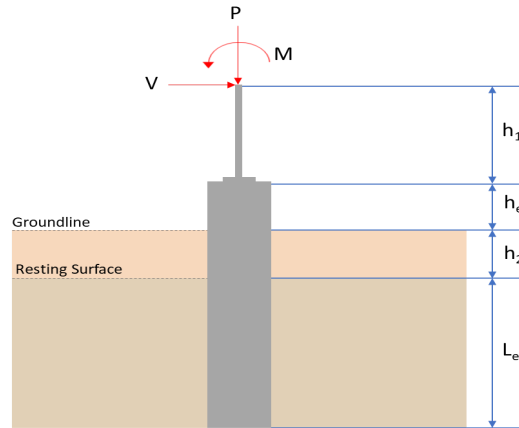
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 6.5$ ft - Total pile length

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

$h_2 = 0$ ft - Depth to resisting surface

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.136	7.640
V_x (kip)	-2.213	-3.702
V_z (kip)	0.389	0.598
M_x (kipft)	1.413	2.149
M_z (kipft)	26.958	45.689

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.213 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35239 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.958 \text{ kipft}) + ((-2.213 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2927 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.0043 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.389 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.061943 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.413 \text{ kipft}) + ((0.389 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.225 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 3.0892 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.0043 \text{ ft}), (3.0892 \text{ ft})]$$

$$L_{e,req} = 6.004 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

Ratio - Embedded depth

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

$$Ratio = \frac{(6.004 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.92369$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.136 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.321 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.321 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.1605$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.625$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.35239 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 4.2927 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2927 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (4.2927 \text{ kipft/ft})) + (4 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4755 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2927 \text{ kipft/ft})) + (3 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (4.2927 \text{ kipft/ft})) + (2 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.22694 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (4.2927 \text{ kipft/ft})) + ((-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.89394 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.4755 \text{ ft})}{2}$$

$$p_a = 0.33566 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22694 \text{ kip/ft}^2)}{(0.33566 \text{ kip/ft}^2)}$$

$$Ratio = 0.67611$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.89394 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.91686$$

Status: **PASS**
Ratio: **0.680**

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

Considering z-direction:

$H_o = 0.061943 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.225 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.225 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (0.061943 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (0.225 \text{ kipft/ft})) + (4 \times (0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.628 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.225 \text{ kipft/ft})) + (3 \times (0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (0.225 \text{ kipft/ft})) + (2 \times (0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.053283 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.225 \text{ kipft/ft})) + ((0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.12108 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.628 \text{ ft})}{2}$$

$$p_a = 0.3471 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.053283 \text{ kip/ft}^2)}{(0.3471 \text{ kip/ft}^2)}$$

$$Ratio = 0.15351$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

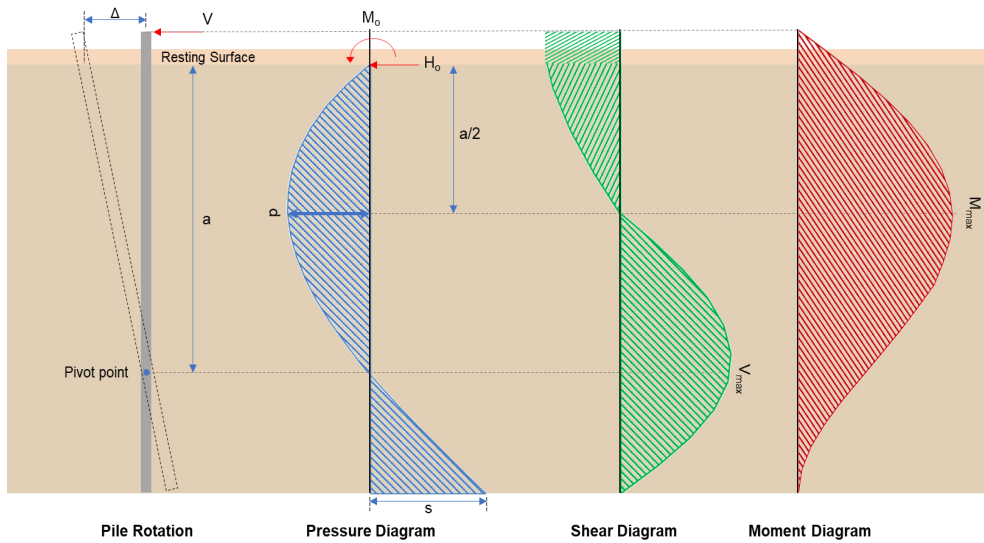
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.12108 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.12419$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.702 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.58949 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(45.689 \text{ kipft}) + ((-3.702 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.2753 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.2753 \text{ kipft/ft})}{(-0.58949 \text{ kip/ft})}$$

$$E = 12.342 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.2753 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (7.2753 \text{ kipft/ft})) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = \frac{6 \times (7.2753 \text{ kipft/ft}) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft}))}{(6 \times (7.2753 \text{ kipft/ft}) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft})))}$$

$$a = 4.4741 \text{ ft}$$

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

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

$$V_{max} = ((-0.58949 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4741 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4741 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4784 \text{ kip}$$

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

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

$$M_{max} = ((-0.58949 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(12.342 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4741 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4741 \text{ ft})}{(2 \times (6.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4741 \text{ ft})}{(2 \times (6.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 29.411 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.598 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.095223 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.149 \text{ kipft}) + ((0.598 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.3422 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.3422 \text{ kipft/ft})}{(0.095223 \text{ kip/ft})}$$

$$E = 3.5936 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.3422 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (0.095223 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (0.3422 \text{ kipft/ft})) + (4 \times (0.095223 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6294 \text{ ft}$$

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

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

$$V_{max} = ((0.095223 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5936 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6294 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (3.5936 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6294 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.62602 \text{ kip}$$

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

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

$$M_{max} = ((0.095223 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.5936 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (3.5936 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5936 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.8134 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.64 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.342 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.342 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Min[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Min[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(7.64 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0028559$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.64 \text{ kip} \rightarrow 7640 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(7640 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.5 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (119.5 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.5 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.5 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.76 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.4784 \text{ kip}$ - Maximum shear force in the x-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.4784 \text{ kip})}{(110.76 \text{ kip})}$$

$$Ratio = 0.085577$$

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

Considering z-direction:

$V_{max} = 0.62602 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.62602 \text{ kip})}{(110.76 \text{ kip})}$$

$$Ratio = 0.0056521$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 29.411 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(29.411 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.11783$$

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

Considering z-direction:

$M_{max} = 1.8134 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(1.8134 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0072654$$

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

REFERENCES	CALCULATIONS	RESULTS
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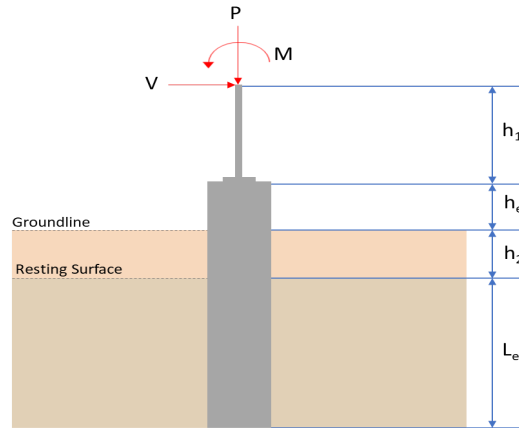
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 6.5$ ft - Total pile length

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

$h_2 = 0$ ft - Depth to resisting surface

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.136	7.640
V_x (kip)	-2.213	-3.702
V_z (kip)	-0.389	-0.598
M_x (kipft)	-1.413	-2.150
M_z (kipft)	26.958	45.689

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.213 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35239 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.958 \text{ kipft}) + ((-2.213 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2927 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.0043 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.389 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.061943 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.413 \text{ kipft}) + ((-0.389 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.225 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.1541 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.0043 \text{ ft}), (2.1541 \text{ ft})]$$

$$L_{e,req} = 6.004 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.004 \text{ ft})}{(6.5 \text{ ft})}$$

$$\text{Ratio} = 0.92369$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.136 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.321 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.321 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.1605$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.625$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.35239 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 4.2927 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2927 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (4.2927 \text{ kipft/ft})) + (4 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4755 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2927 \text{ kipft/ft})) + (3 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (4.2927 \text{ kipft/ft})) + (2 \times (-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.22694 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (4.2927 \text{ kipft/ft})) + ((-0.35239 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.89394 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.4755 \text{ ft})}{2}$$

$$p_a = 0.33566 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22694 \text{ kip/ft}^2)}{(0.33566 \text{ kip/ft}^2)}$$

$$Ratio = 0.67611$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.89394 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.91686$$

Status: **PASS**
Ratio: **0.680**

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

Considering z-direction:

$H_o = -0.061943 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.225 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.225 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.061943 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (0.225 \text{ kipft/ft})) + (4 \times (-0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.628 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.225 \text{ kipft/ft})) + (3 \times (-0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (0.225 \text{ kipft/ft})) + (2 \times (-0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = -0.012918 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.225 \text{ kipft/ft})) + ((-0.061943 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.0067275 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.628 \text{ ft})}{2}$$

$$p_a = 0.3471 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.012918 \text{ kip/ft}^2)}{(0.3471 \text{ kip/ft}^2)}$$

$$Ratio = -0.037218$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

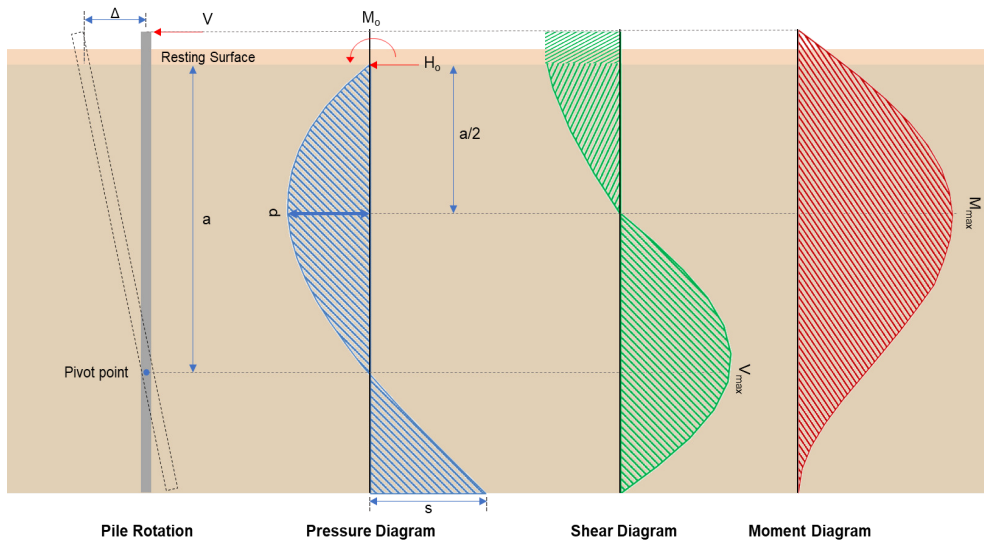
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0067275 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.0069$$

Status: **PASS**
Ratio: **-0.040**

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.702 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.58949 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(45.689 \text{ kipft}) + ((-3.702 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.2753 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.2753 \text{ kipft/ft})}{(-0.58949 \text{ kip/ft})}$$

$$E = 12.342 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.2753 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (7.2753 \text{ kipft/ft})) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = \frac{(6 \times (7.2753 \text{ kipft/ft})) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft}))}{(6 \times (7.2753 \text{ kipft/ft})) + (4 \times (-0.58949 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4741 \text{ ft}$$

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

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

$$V_{max} = ((-0.58949 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4741 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4741 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4784 \text{ kip}$$

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

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

$$M_{max} = ((-0.58949 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(12.342 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4741 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4741 \text{ ft})}{(2 \times (6.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (12.342 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4741 \text{ ft})}{(2 \times (6.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 29.411 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.598 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.095223 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.15 \text{ kipft}) + ((-0.598 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.34236 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.34236 \text{ kipft/ft})}{(-0.095223 \text{ kip/ft})}$$

$$E = 3.5953 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.34236 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.095223 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (0.34236 \text{ kipft/ft})) + (4 \times (-0.095223 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6294 \text{ ft}$$

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

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

$$V_{max} = ((-0.095223 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5953 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6294 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (3.5953 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6294 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.62619 \text{ kip}$$

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

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

$$M_{max} = ((-0.095223 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.5953 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (3.5953 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5953 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6294 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.814 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.64 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.342 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.342 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Min[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Min[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(7.64 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0028559$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.64 \text{ kip} \rightarrow 7640 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(7640 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.5 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (119.5 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.5 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.5 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.76 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.4784 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(9.4784 \text{ kip})}{(110.76 \text{ kip})}$$

$$Ratio = 0.085577$$

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

Considering z-direction:

$V_{max} = 0.62619 \text{ kip}$ - Maximum shear force in the z-direction,
Ratio - Capacity

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

$$Ratio = \frac{(0.62619 \text{ kip})}{(110.76 \text{ kip})}$$

$$Ratio = 0.0056537$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 29.411 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(29.411 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.11783$$

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

Considering z-direction:

$M_{max} = 1.814 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.814 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0072676$$

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

REFERENCES	CALCULATIONS	RESULTS
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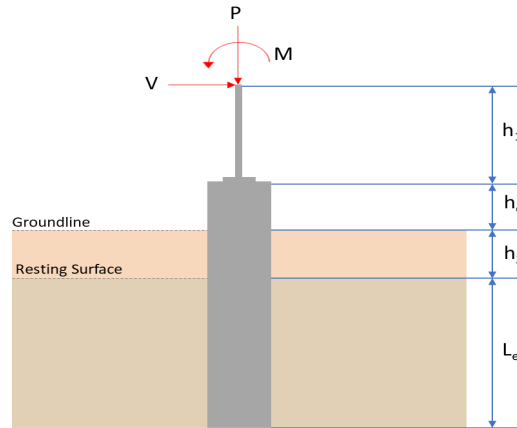
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7$ ft - Total pile length

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

$h_2 = 0$ ft - Depth to resisting surface

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.057	10.536
V_x (kip)	-3.042	-5.076
V_z (kip)	-0.031	-0.055
M_x (kipft)	-0.106	-0.189
M_z (kipft)	37.347	63.436

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.042 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.48439 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.347 \text{ kipft}) + ((-3.042 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.947 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.5777 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.031 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0049363 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((-0.031 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016879 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.0161 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.5777 \text{ ft}), (1.0161 \text{ ft})]$$

$$L_{e,req} = 6.578 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.578 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.93971$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.057 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.44106 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.44106 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.22053$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.48439 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.947 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.947 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.947 \text{ kipft/ft})) + (4 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8273 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.947 \text{ kipft/ft})) + (3 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.947 \text{ kipft/ft})) + (2 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25657 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.947 \text{ kipft/ft})) + ((-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0412 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8273 \text{ ft})}{2}$$

$$p_a = 0.36205 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.25657 \text{ kip/ft}^2)}{(0.36205 \text{ kip/ft}^2)}$$

$$Ratio = 0.70866$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.0412 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.99163$$

Status: **PASS**
Ratio: **0.710**

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = -0.0049363 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.016879 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016879 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.0049363 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.016879 \text{ kipft/ft})) + (4 \times (-0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0033 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.016879 \text{ kipft/ft})) + (3 \times (-0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 [(3 \times (0.016879 \text{ kipft/ft})) + (2 \times (-0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = -0.0010827 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 [(2 \times (0.016879 \text{ kipft/ft})) + ((-0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = -0.000097491 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0033 \text{ ft})}{2}$$

$$p_a = 0.37525 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.0010827 \text{ kip/ft}^2)}{(0.37525 \text{ kip/ft}^2)}$$

$$Ratio = -0.0028852$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

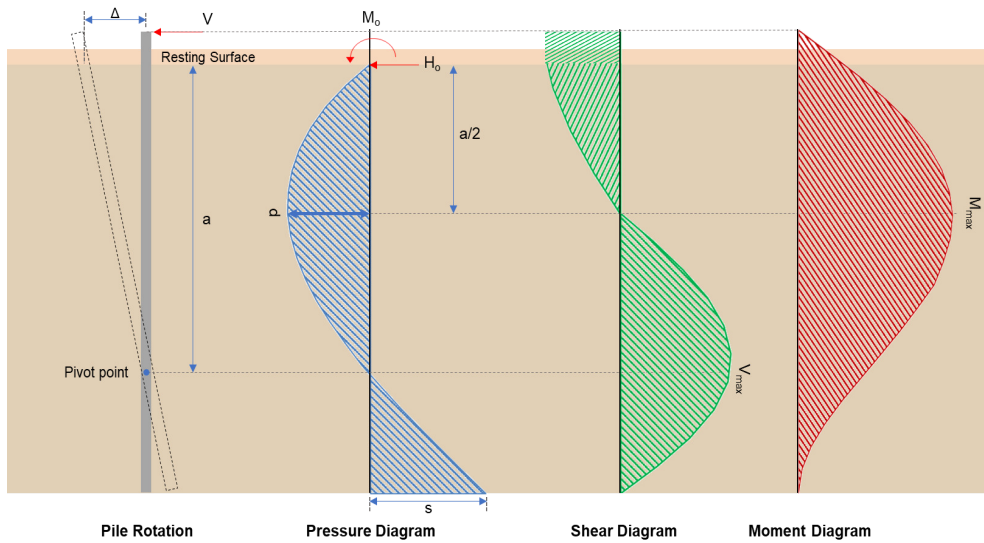
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(-0.000097491 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = -0.000092849$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.076 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.80828 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.436 \text{ kipft}) + ((-5.076 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.101 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.101 \text{ kipft/ft})}{(-0.80828 \text{ kip/ft})}$$

$$E = 12.497 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.101 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (10.101 \text{ kipft/ft})) + (4 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = \frac{(-0.80828 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (10.101 \text{ kipft/ft})) + (4 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8253 \text{ ft}$$

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

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

$$V_{max} = ((-0.80828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8253 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8253 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.347 \text{ kip}$$

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

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

$$M_{max} = ((-0.80828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.497 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 41.158 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.055 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.008758 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.189 \text{ kipft}) + ((-0.055 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.030096 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.030096 \text{ kipft/ft})}{(-0.008758 \text{ kip/ft})}$$

$$E = 3.4364 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.030096 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.008758 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.030096 \text{ kipft/ft})) + (4 \times (-0.008758 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0026 \text{ ft}$$

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

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

$$V_{max} = ((-0.008758 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4364 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0026 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.4364 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0026 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.053778 \text{ kip}$$

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

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

$$M_{max} = ((-0.008758 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.4364 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0026 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.4364 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0026 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.4364 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0026 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.16636 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\left(\frac{10.536 \text{ kip}}{(0.65) \times (0.8)} \right) - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.246 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.246 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$</p> <p>$s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(10.536 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0039384$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.536 \text{ kip} \rightarrow 10536 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(10536 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.89 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.89 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.89 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.89 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.01 \text{ kip}$$

Considering x-direction:

V_{max} = 12.347 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.347 \text{ kip})}{(111.01 \text{ kip})}$$

$$Ratio = 0.11122$$

Considering z-direction:

$V_{max} = 0.053778 \text{ kip}$ - Maximum shear force in the z-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.053778 \text{ kip})}{(111.01 \text{ kip})}$$

$$Ratio = 0.00048445$$

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

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 41.158 \text{ kipft}$ - Maximum moment in the x-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(41.158 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.16489$$

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

Considering z-direction:

$M_{max} = 0.16636 \text{ kipft}$ - Maximum moment in the z-direction,

$Ratio$ - Capacity

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

$$\text{Ratio} = \frac{(0.16636 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00066649$$

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

REFERENCES	CALCULATIONS	RESULTS
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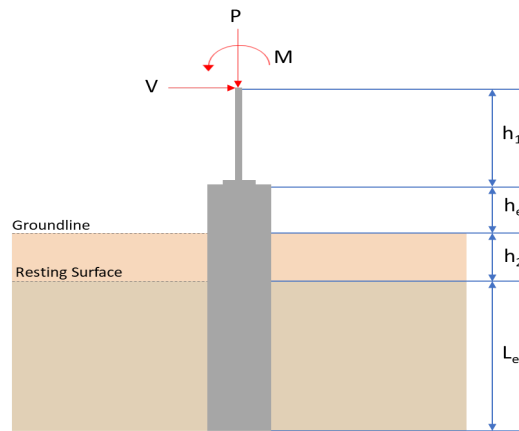
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7$ ft - Total pile length

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

$h_2 = 0$ ft - Depth to resisting surface

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.057	10.536
V_x (kip)	-3.042	-5.076
V_z (kip)	0.031	0.055
M_x (kipft)	0.106	0.190
M_z (kipft)	37.347	63.436

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.042 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.48439 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.347 \text{ kipft}) + ((-3.042 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.947 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.5777 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.031 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0049363 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((0.031 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016879 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.1945 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.5777 \text{ ft}), (1.1945 \text{ ft})]$$

$$L_{e,req} = 6.578 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.578 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.93971$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.057 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.44106 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.44106 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.22053$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.48439 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.947 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.947 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.947 \text{ kipft/ft})) + (4 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8273 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.947 \text{ kipft/ft})) + (3 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.947 \text{ kipft/ft})) + (2 \times (-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25657 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.947 \text{ kipft/ft})) + ((-0.48439 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0412 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8273 \text{ ft})}{2}$$

$$p_a = 0.36205 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.25657 \text{ kip/ft}^2)}{(0.36205 \text{ kip/ft}^2)}$$

$$Ratio = 0.70866$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.0412 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.99163$$

Status: **PASS**
Ratio: **0.710**

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = 0.0049363 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.016879 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016879 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.0049363 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.016879 \text{ kipft/ft})) + (4 \times (0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0033 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.016879 \text{ kipft/ft})) + (3 \times (0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.016879 \text{ kipft/ft})) + (2 \times (0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.0037455 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.016879 \text{ kipft/ft})) + ((0.0049363 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.0083647 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0033 \text{ ft})}{2}$$

$$p_a = 0.37525 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0037455 \text{ kip/ft}^2)}{(0.37525 \text{ kip/ft}^2)}$$

$$Ratio = 0.0099812$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

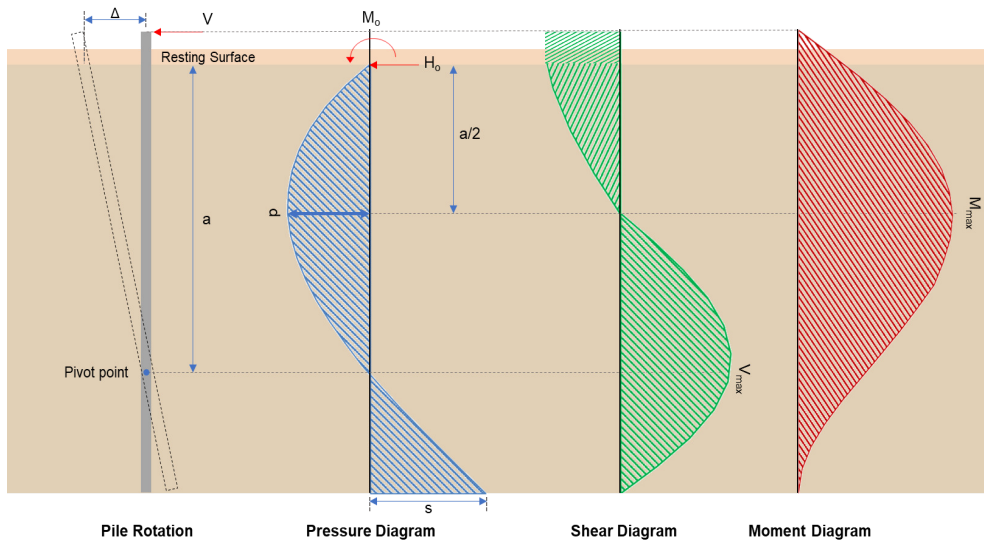
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0083647 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.0079664$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.076 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.80828 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.436 \text{ kipft}) + ((-5.076 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.101 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.101 \text{ kipft/ft})}{(-0.80828 \text{ kip/ft})}$$

$$E = 12.497 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.101 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (10.101 \text{ kipft/ft})) + (4 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = \frac{(6 \times (10.101 \text{ kipft/ft})) + (4 \times (-0.80828 \text{ kip/ft}) \times (7 \text{ ft}))}{}$$

$$a = 4.8253 \text{ ft}$$

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

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

$$V_{max} = ((-0.80828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8253 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8253 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.347 \text{ kip}$$

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

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

$$M_{max} = ((-0.80828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.497 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.497 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8253 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 41.158 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.055 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.008758 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.19 \text{ kipft}) + ((0.055 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.030255 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.030255 \text{ kipft/ft})}{(0.008758 \text{ kip/ft})}$$

$$E = 3.4545 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.030255 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.008758 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.030255 \text{ kipft/ft})) + (4 \times (0.008758 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0019 \text{ ft}$$

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

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

$$V_{max} = ((0.008758 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4545 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0019 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (3.4545 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0019 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.053937 \text{ kip}$$

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

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

$$M_{max} = ((0.008758 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.4545 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0019 \text{ ft})}{2 \times (7 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (3.4545 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0019 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.4545 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0019 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.16691 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(10.536 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.246 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.246 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>Ratio - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(10.536 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0039384$	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.536 \text{ kip} \rightarrow 10536 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(10536 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.89 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.89 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.89 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.89 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.01 \text{ kip}$$

Considering x-direction:

V_{max} = 12.347 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.347 \text{ kip})}{(111.01 \text{ kip})}$$

$$Ratio = 0.11122$$

Considering z-direction:

$V_{max} = 0.053937 \text{ kip}$ - Maximum shear force in the z-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.053937 \text{ kip})}{(111.01 \text{ kip})}$$

$$Ratio = 0.00048588$$

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

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 41.158 \text{ kipft}$ - Maximum moment in the x-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(41.158 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.16489$$

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

Considering z-direction:

$M_{max} = 0.16691 \text{ kipft}$ - Maximum moment in the z-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.16691 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00066872$$

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