Your Project Calculations

Project Name: MARTA - Structure 1 - 5x9 - RevA - Jb

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MARTA%20-%20Structure%201%20-%205x9%20-%20RevA%20-%20Jb&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/4_2024

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=BnWDQPmpCxPRC5KaKnFozx1rxSd4se6gDsalenvhqURRqYykUFqqTrvSopvc6qtz

Array Specification

Product:	Beam
Unique ID:	4P-17-8TOP-HD-45-L-5Hx9W-2ED7
Duty Classification:	HD
Module Width:	41.20 in
Module Length:	87.30in
Number of Rows:	5
Number of Columns:	9
Total Number of Modules:	45
Desired Tilt Angle:	45
Front Edge Clearance:	10
Total Array Height at Tilt:	22.21 ft
Total Frame Length:	66.00 ft
Frame Weight:	4022 lbs
Array Dimensions N/S:	17.38 ft
Array Dimensions E/W:	66.22 ft
Rail Length:	208.50 in
Rail Spacing:	3.64 ft
Rail Check:	Not Checked

Support Specifications

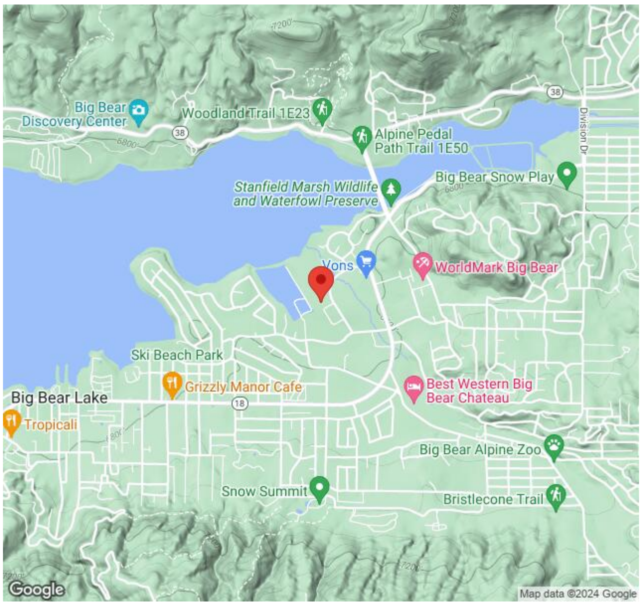
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	16.14 ft
Number of Poles:	4
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 7.50 ft Pile 3: 7.50 ft Pile 4: 7.50 ft
Foundation Volume:	17.778 y^3
Foundation Result:	PASSED
Mount Twist:	0.200018 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	170 Business Center Dr, Big Bear Lake, CA 92315, USA
Wind Speed:	100 mph
Snow Load:	70 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.019244 ksf



Design Disclaimer

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

AutoDesigner Input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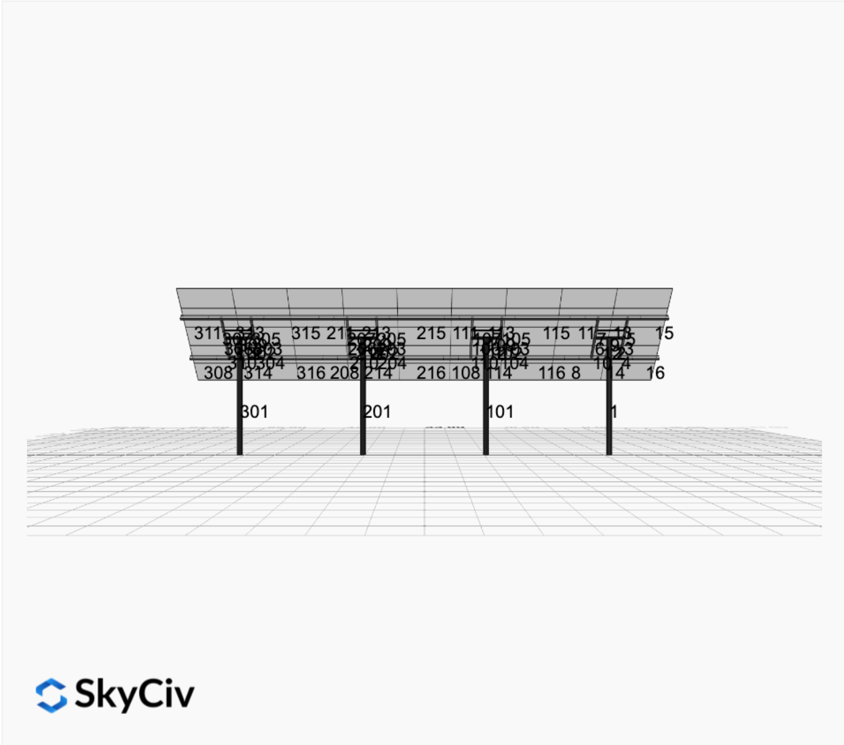
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)
- Foundation Design and Sizing is approximate only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101
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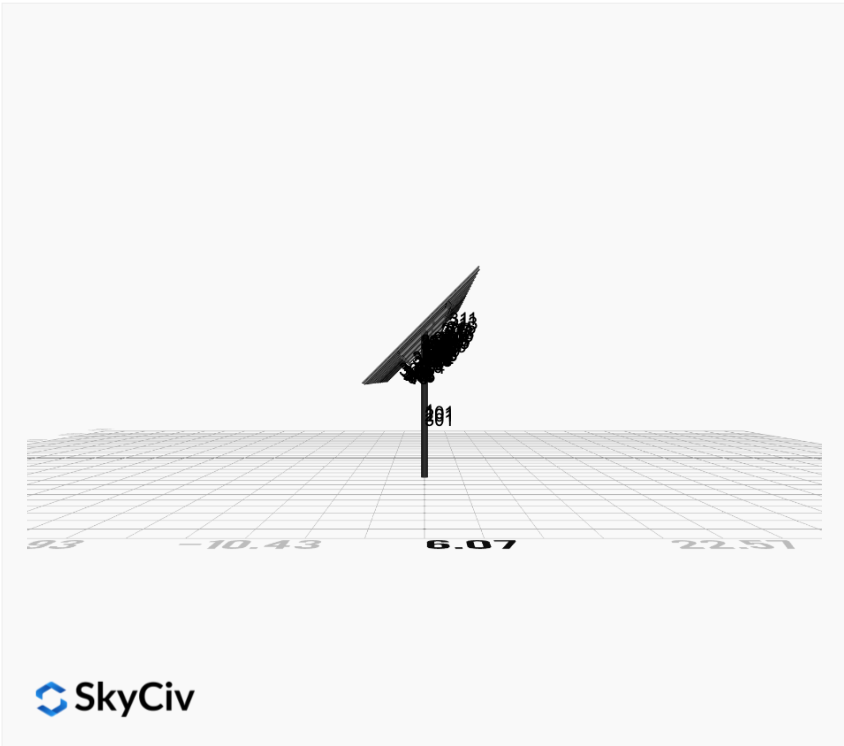
SkyCiv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6.07
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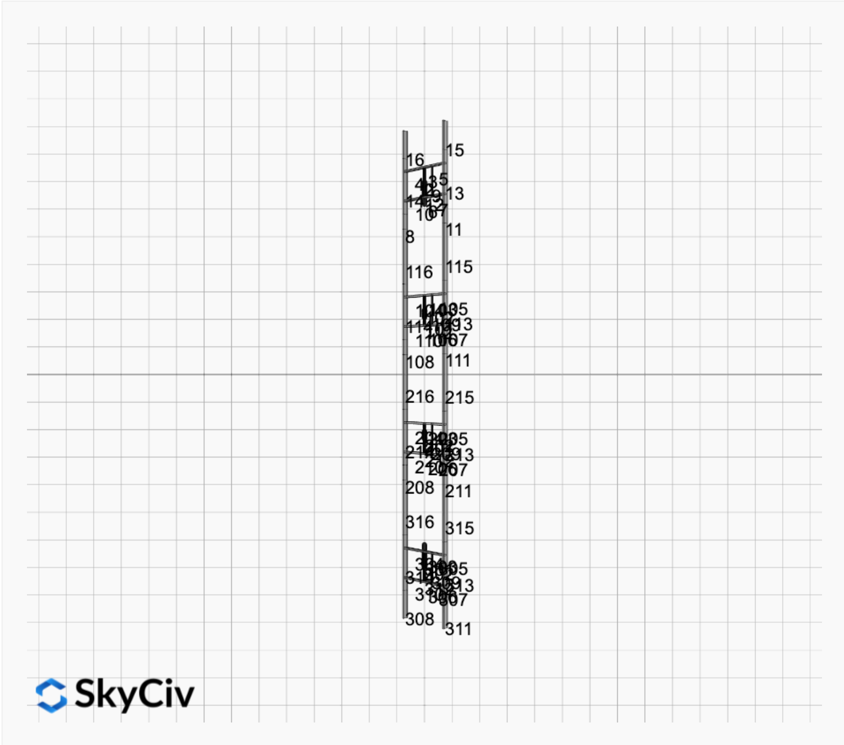
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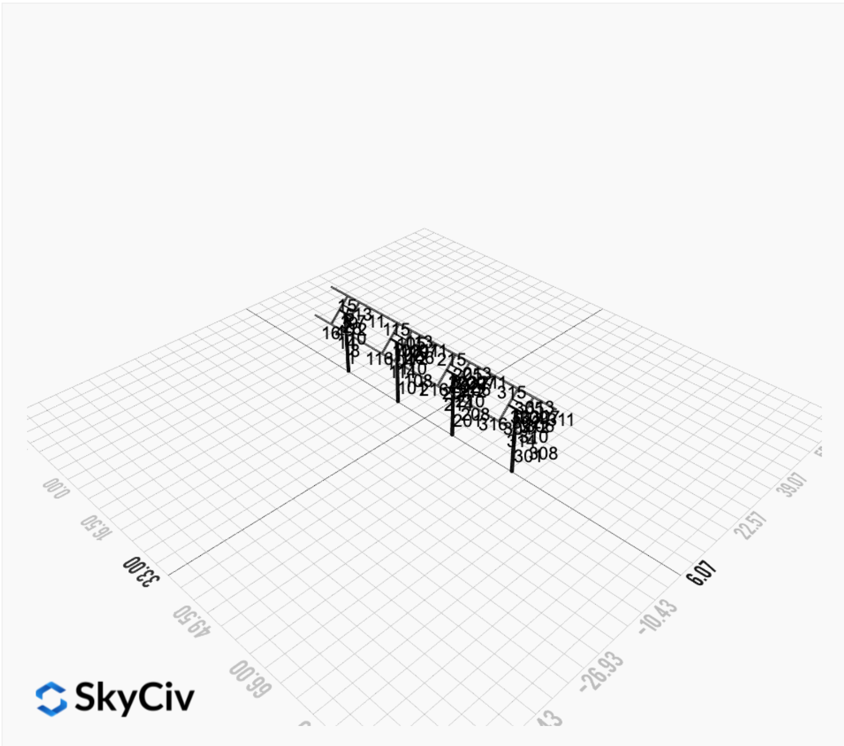
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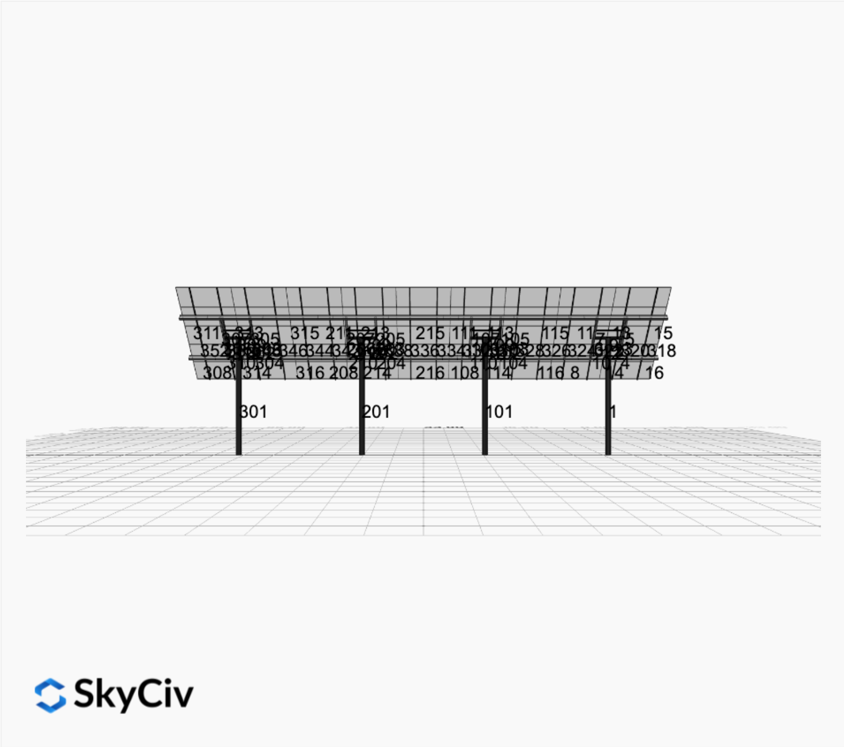
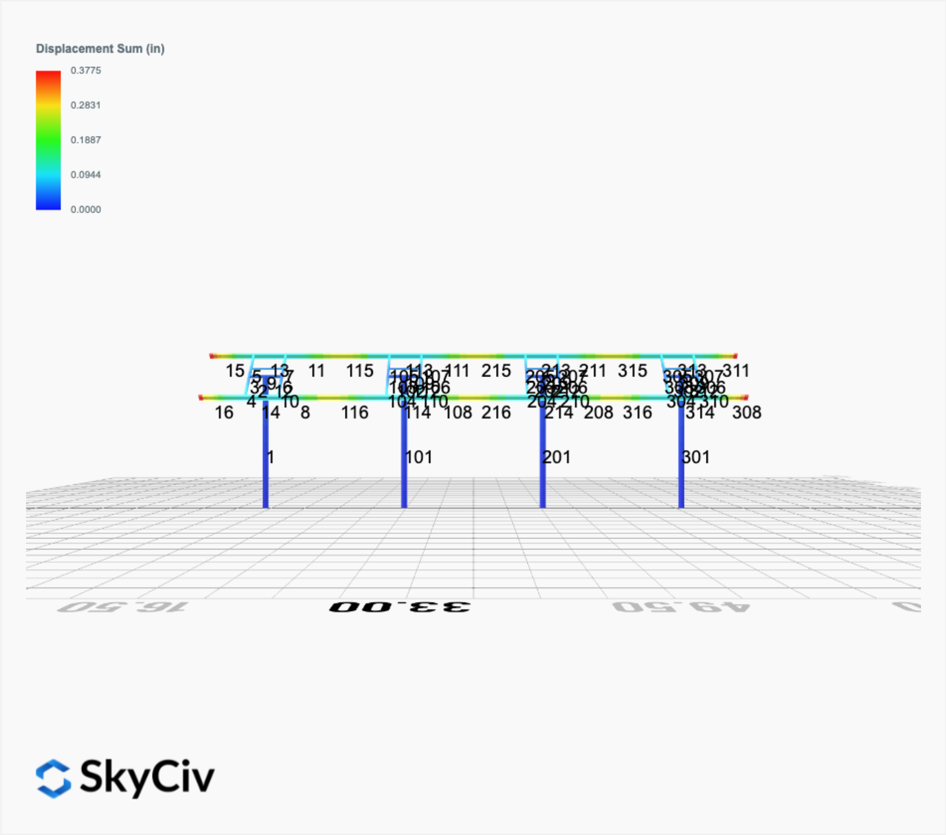
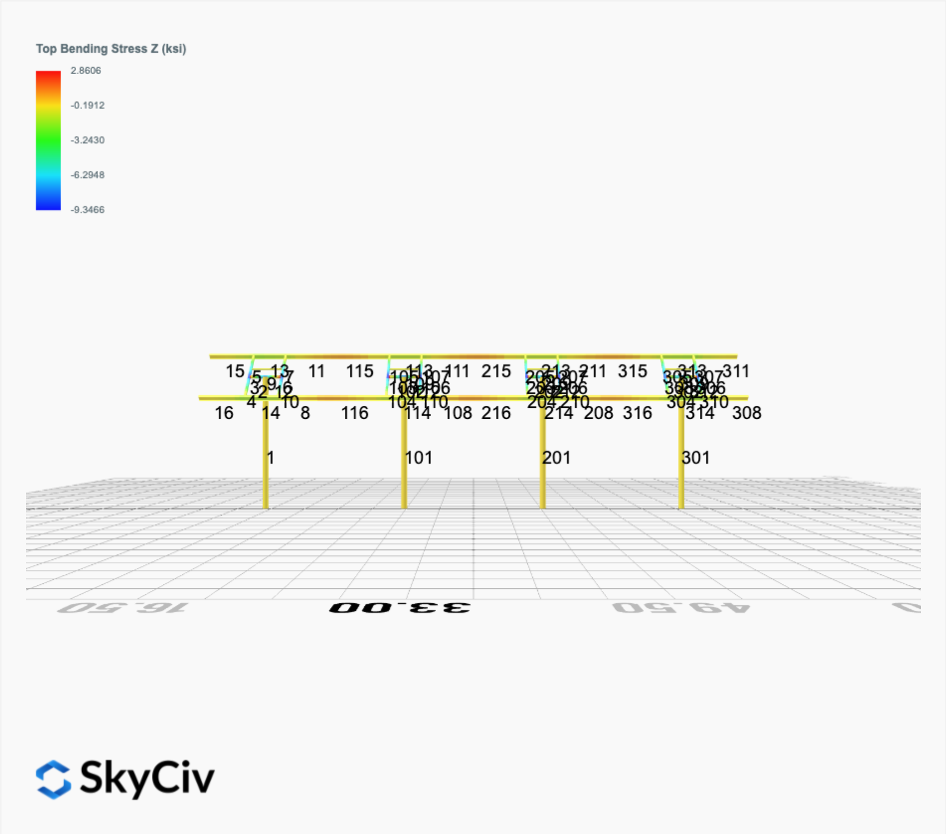
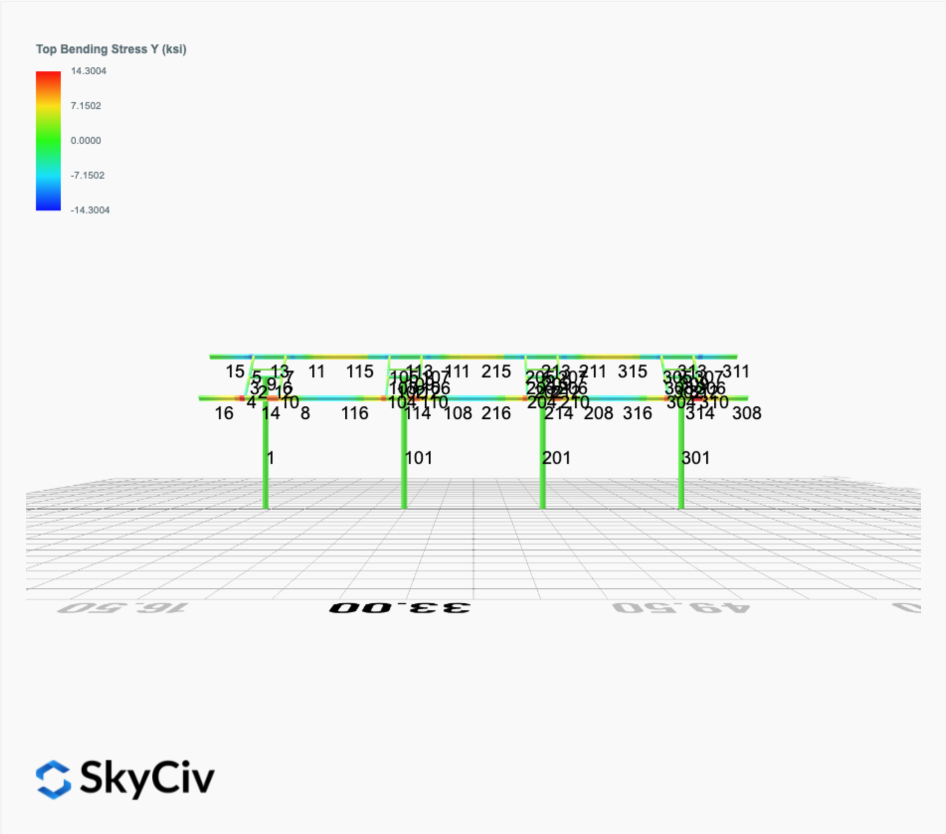
33.00
49.50
66.00
39.07
22.57
6.07
-10.43
-26.93


301
201
101
1

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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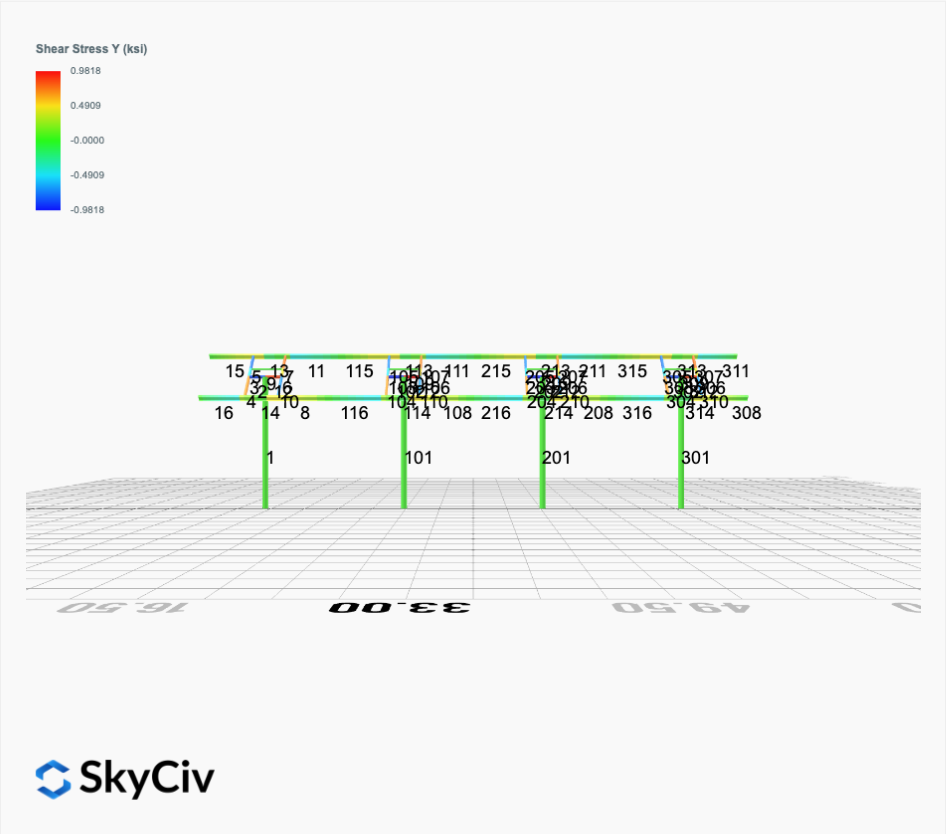
7.1502
0.0000
-7.1502
-14.3004
SkyCiv


Shear Stress Y (ksi)
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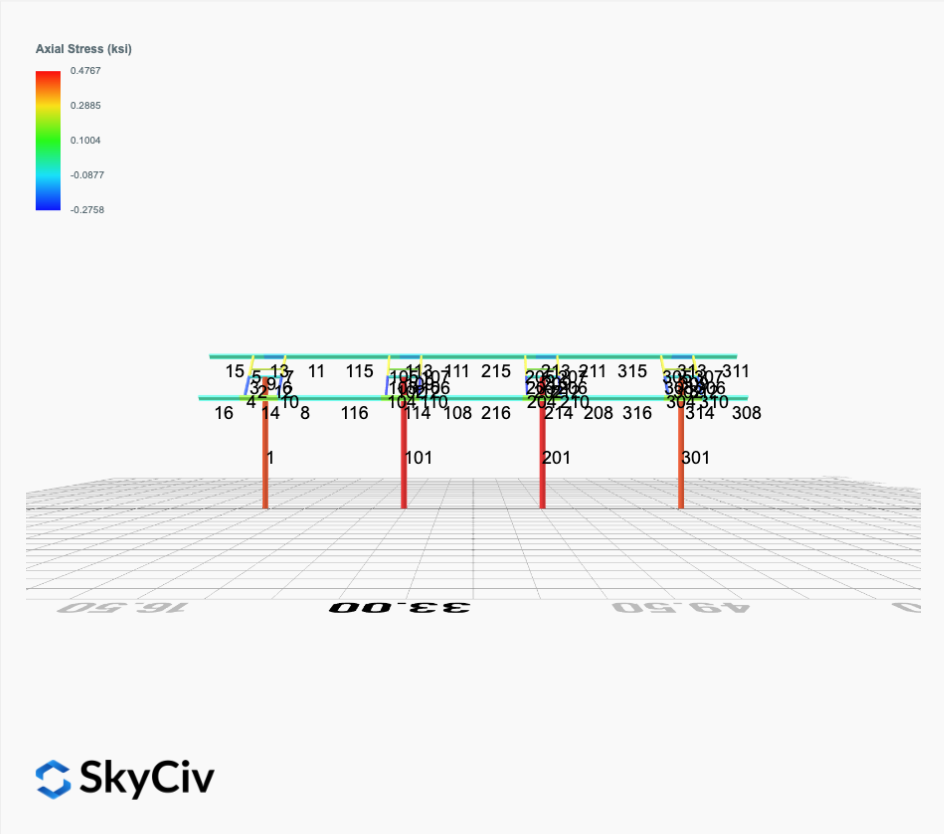
-0.4909
-0.9818
SkyCiv



Axial Stress (ksi)
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-0.0877
-0.2758
1
101
201
301
16.50
33.00
49.50
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0042	2.2488	-0.0035	-0.0167	0.0354	0.0846
ULS: 2. D + L	-0.0042	2.2488	-0.0035	-0.0167	0.0354	0.0846
ULS: 3. D + (S or Lr or R)	-0.0143	6.0473	-0.0116	-0.0556	0.1197	0.2526
ULS: 3. D + (S or Lr or R)	-0.0042	2.2488	-0.0035	-0.0167	0.0354	0.0846
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0118	5.0977	-0.0095	-0.0459	0.0986	0.2106
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0042	2.2488	-0.0035	-0.0167	0.0354	0.0846
ULS: 5b. D + 0.7E	-0.0042	2.2488	-0.0035	-0.0167	0.0354	0.0846
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0118	5.0977	-0.0095	-0.0459	0.0986	0.2106
ULS: 8. 0.6D + 0.7E	-0.0025	1.3493	-0.0021	-0.0100	0.0212	0.0508
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4152	4.6415	-0.0008	-0.0038	0.0118	40.8396
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4152	4.6415	-0.0008	-0.0038	0.0118	40.8396
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7377	0.5186	-0.0043	-0.0205	0.0465	-27.0647
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5368	0.7209	-0.0061	-0.0299	0.0560	-28.6717
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8200	6.8922	-0.0076	-0.0363	0.0809	30.7769
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8200	6.8922	-0.0076	-0.0363	0.0809	30.7769
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2947	3.8000	-0.0102	-0.0487	0.1070	-20.1513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1440	3.9518	-0.0115	-0.0558	0.1141	-21.3566
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8125	4.0433	-0.0015	-0.0070	0.0177	30.6509
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8125	4.0433	-0.0015	-0.0070	0.0177	30.6509
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3022	0.9511	-0.0041	-0.0195	0.0437	-20.2774
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1515	1.1029	-0.0055	-0.0266	0.0509	-21.4826
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4135	3.7420	0.0006	0.0029	-0.0024	40.8058
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4135	3.7420	0.0006	0.0029	-0.0024	40.8058
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7394	-0.3809	-0.0029	-0.0138	0.0324	-27.0985
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5385	-0.1786	-0.0048	-0.0232	0.0419	-28.7055

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.7706
Shear X	-4.0306
Shear Z	-0.0204
Moment X	-0.0987
Moment Y (Twist)	0.2003
Moment Z	70.2230

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	6.8922
Shear X	-2.4152
Shear Z	-0.0116
Moment X	-0.0558
Moment Y (Twist)	0.1197
Moment Z	40.8396

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	0.0043	2.3336	0.0004	0.0023	-0.0012	-0.0393
ULS: 2. D + L	0.0043	2.3336	0.0004	0.0023	-0.0012	-0.0393
ULS: 3. D + (S or Lr or R)	0.0143	6.3372	0.0014	0.0077	-0.0039	-0.1671
ULS: 3. D + (S or Lr or R)	0.0043	2.3336	0.0004	0.0023	-0.0012	-0.0393
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0118	5.3363	0.0012	0.0063	-0.0032	-0.1352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0043	2.3336	0.0004	0.0023	-0.0012	-0.0393
ULS: 5b. D + 0.7E	0.0043	2.3336	0.0004	0.0023	-0.0012	-0.0393

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0118	5.3363	0.0012	0.0063	-0.0032	-0.1352
ULS: 8. 0.6D + 0.7E	0.0026	1.4002	0.0003	0.0014	-0.0007	-0.0236
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4578	4.8139	0.0121	0.0614	-0.0654	41.5399
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4578	4.8139	0.0121	0.0614	-0.0654	41.5399
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7874	0.5387	-0.0074	-0.0370	0.0415	-27.7507
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5736	0.7510	-0.0076	-0.0382	0.0435	-29.3322
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8347	7.1965	0.0099	0.0507	-0.0514	31.0492
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8347	7.1965	0.0099	0.0507	-0.0514	31.0492
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3492	3.9901	-0.0047	-0.0231	0.0288	-20.9188
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1888	4.1493	-0.0049	-0.0240	0.0302	-22.1049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8423	4.1939	0.0092	0.0466	-0.0493	31.1451
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8423	4.1939	0.0092	0.0466	-0.0493	31.1451
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3416	0.9874	-0.0054	-0.0272	0.0308	-20.8229
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1813	1.1467	-0.0056	-0.0281	0.0323	-22.0090
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4595	3.8805	0.0119	0.0605	-0.0649	41.5556
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4595	3.8805	0.0119	0.0605	-0.0649	41.5556
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7857	-0.3948	-0.0076	-0.0380	0.0420	-27.7350
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5719	-0.1824	-0.0078	-0.0391	0.0439	-29.3165

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.2724
Shear X	-4.1034
Shear Z	0.0211
Moment X	0.1073
Moment Y (Twist)	0.1137
Moment Z	71.3452

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	7.1965
Shear X	-2.4595
Shear Z	0.0121
Moment X	0.0614
Moment Y (Twist)	0.0654
Moment Z	41.5556

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	0.0043	2.3336	-0.0004	-0.0023	0.0012	-0.0393
ULS: 2. D + L	0.0043	2.3336	-0.0004	-0.0023	0.0012	-0.0393
ULS: 3. D + (S or Lr or R)	0.0143	6.3372	-0.0014	-0.0077	0.0039	-0.1671
ULS: 3. D + (S or Lr or R)	0.0043	2.3336	-0.0004	-0.0023	0.0012	-0.0393
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0118	5.3363	-0.0012	-0.0063	0.0032	-0.1352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0043	2.3336	-0.0004	-0.0023	0.0012	-0.0393
ULS: 5b. D + 0.7E	0.0043	2.3336	-0.0004	-0.0023	0.0012	-0.0393
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0118	5.3363	-0.0012	-0.0063	0.0032	-0.1352
ULS: 8. 0.6D + 0.7E	0.0026	1.4002	-0.0003	-0.0014	0.0007	-0.0236
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4578	4.8139	-0.0121	-0.0614	0.0654	41.5399
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4578	4.8139	-0.0121	-0.0614	0.0654	41.5399
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7874	0.5387	0.0074	0.0370	-0.0415	-27.7507
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5736	0.7510	0.0076	0.0382	-0.0435	-29.3322
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8347	7.1965	-0.0099	-0.0507	0.0514	31.0492
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8347	7.1965	-0.0099	-0.0507	0.0514	31.0492
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3492	3.9901	0.0047	0.0231	-0.0288	-20.9188
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1888	4.1493	0.0049	0.0240	-0.0302	-22.1049

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	-1.8423	4.1939	-0.0092	-0.0466	0.0493	31.1451
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8423	4.1939	-0.0092	-0.0466	0.0493	31.1451
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3416	0.9874	0.0054	0.0272	-0.0308	-20.8229
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1813	1.1467	0.0056	0.0281	-0.0323	-22.0090
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4595	3.8805	-0.0119	-0.0605	0.0649	41.5556
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4595	3.8805	-0.0119	-0.0605	0.0649	41.5556
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7857	-0.3948	0.0076	0.0380	-0.0420	-27.7350
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5719	-0.1824	0.0078	0.0391	-0.0439	-29.3165

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.2724
Shear X	-4.1034
Shear Z	-0.0211
Moment X	-0.1075
Moment Y (Twist)	0.1134
Moment Z	71.3458

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	7.1965
Shear X	-2.4595
Shear Z	-0.0121
Moment X	-0.0614
Moment Y (Twist)	0.0654
Moment Z	41.5556

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	-0.0043	2.2488	0.0035	0.0167	-0.0354	0.0846
ULS: 2. D + L	-0.0043	2.2488	0.0035	0.0167	-0.0354	0.0846
ULS: 3. D + (S or Lr or R)	-0.0143	6.0473	0.0116	0.0556	-0.1197	0.2526
ULS: 3. D + (S or Lr or R)	-0.0043	2.2488	0.0035	0.0167	-0.0354	0.0846
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0118	5.0977	0.0095	0.0459	-0.0986	0.2106
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0043	2.2488	0.0035	0.0167	-0.0354	0.0846
ULS: 5b. D + 0.7E	-0.0043	2.2488	0.0035	0.0167	-0.0354	0.0846
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0118	5.0977	0.0095	0.0459	-0.0986	0.2106
ULS: 8. 0.6D + 0.7E	-0.0026	1.3493	0.0021	0.0100	-0.0212	0.0508
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4152	4.6415	0.0008	0.0038	-0.0118	40.8396
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4152	4.6415	0.0008	0.0038	-0.0118	40.8396
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7377	0.5186	0.0043	0.0205	-0.0465	-27.0647
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5368	0.7209	0.0061	0.0299	-0.0560	-28.6716
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8200	6.8922	0.0076	0.0363	-0.0809	30.7769
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8200	6.8922	0.0076	0.0363	-0.0809	30.7769
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2947	3.8000	0.0102	0.0488	-0.1070	-20.1513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1440	3.9518	0.0115	0.0558	-0.1141	-21.3566
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8125	4.0433	0.0015	0.0070	-0.0177	30.6509
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8125	4.0433	0.0015	0.0070	-0.0177	30.6509
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3022	0.9511	0.0041	0.0195	-0.0437	-20.2774
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1515	1.1029	0.0055	0.0266	-0.0509	-21.4826
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4135	3.7420	-0.0006	-0.0029	0.0024	40.8058
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4135	3.7420	-0.0006	-0.0029	0.0024	40.8058
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7394	-0.3809	0.0029	0.0138	-0.0324	-27.0985
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5385	-0.1786	0.0048	0.0232	-0.0419	-28.7055

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.7706
Shear X	-4.0306
Shear Z	0.0204
Moment X	0.0990
Moment Y (Twist)	0.2000
Moment Z	70.2242

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	6.8922
Shear X	-2.4152
Shear Z	0.0116
Moment X	0.0558
Moment Y (Twist)	0.1197
Moment Z	40.8396

Project Details

Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	MARTA - Structure 1 - 5x9 - RevA - Jb
Unit System:	imperial

Design Input Information

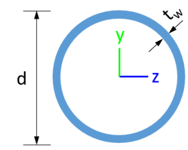
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

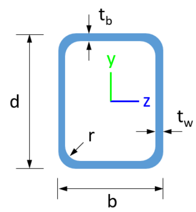
Design Materials

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

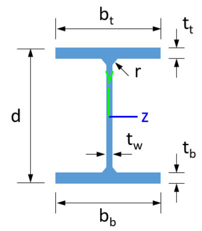
Section Dimensions



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_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85

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_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	33.90	33.90	16.14	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.59,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.72,1.67,1.67,1.66,1.64	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	1.96,1.96,1.96,1.96,1.96,1.96,1.97,1.97,2.02,2.02,1.97,1.97,2.00,1.74,1.97,1.97,1.95,1.98,1.97,1.97,2.03,2.02,1.97,1.97,1.99,1.82	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.72,1.67,1.67,1.66,1.64	300	200	1
11	19	1.33	1.33	2.05	1.92,1.92,1.92,1.93,1.92,1.92,2.03,2.03,2.08,2.05,2.03,2.03,2.04,2.04,1.99,1.99,1.85,1.78,2.03,2.03,2.08,2.05,2.03,2.03,2.04,2.04	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.08,1.10,1.11,1.11,1.10,1.11,1.12,1.12,1.13,1.13,1.11,1.11,1.08,1.10,1.11,1.11,1.10,1.11	300	200	1
14	19	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.10,1.33,1.11,1.11,1.11,1.03,1.11,1.11,1.12,1.12,1.11,1.11,1.10,1.31,1.11,1.11,1.11,1.06	300	200	1
15	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	33.90	33.90	16.14	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.64	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	30	20	1

						0	0	
108	19	1.33	1.33	2.05	1.61,1.61,1.61,1.62,1.61,1.61,1.55,1.55,1.45,2.05,1.54,1.54,1.52,1.21,1.58,1.58,1.68,1.66,1.55,1.55,1.46,2.05,1.54,1.54,1.53,1.32	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.64	300	200	1
111	19	1.33	1.33	2.05	1.66,1.67,1.66,1.67,1.67,1.66,1.53,1.53,1.29,1.42,1.51,1.51,1.42,1.48,1.59,1.59,1.85,1.97,1.53,1.53,1.29,1.42,1.51,1.51,1.44,1.49	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.11,1.11,1.07,1.07,1.07,1.08,1.06,1.06,1.06,1.05,1.07,1.07,1.11,1.12,1.07,1.07,1.07,1.08	300	200	1
114	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.23,1.06,1.06,1.06,1.09,1.06,1.06,1.06,1.07,1.06,1.06,1.08,1.21,1.06,1.06,1.06,1.07	300	200	1
115	19	4.84	4.84	7.45	1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.12,1.08,1.09,1.12,1.12,1.10,1.11,1.13,1.13,1.16,1.17,1.12,1.12,1.08,1.09,1.12,1.12,1.10,1.11	300	200	1
116	19	4.84	4.84	7.45	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.11,1.18,1.12,1.12,1.12,1.06,1.13,1.13,1.14,1.14,1.13,1.13,1.11,1.18,1.12,1.12,1.12,1.09	300	200	1
201	9	33.90	33.90	16.14	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.64	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
208	19	1.33	1.33	2.05	1.66,1.67,1.66,1.67,1.66,1.66,1.60,1.60,1.47,2.04,1.59,1.59,1.55,1.21,1.63,1.63,1.74,1.72,1.60,1.60,1.48,2.04,1.58,1.58,1.56,1.34	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.64	300	200	1
211	19	1.33	1.33	2.05	1.73,1.74,1.73,1.74,1.73,1.73,1.55,1.55,1.24,1.40,1.53,1.53,1.42,1.48,1.63,1.63,1.96,2.03,1.56,1.56,1.25,1.40,1.52,1.52,1.44,1.49	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.11,1.11,1.07,1.07,1.07,1.08,1.06,1.06,1.06,1.05,1.07,1.07,1.12,1.12,1.07,1.07,1.07,1.08	300	200	1
214	19	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.23,1.06,1.06,1.06,1.08,1.06,1.06,1.06,1.07,1.06,1.06,1.08,1.21,1.06,1.06,1.06,1.07	300	200	1
215	19	4.84	4.84	7.45	1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.12,1.09,1.11,1.12,1.12,1.11,1.12,1.13,1.13,1.15,1.16,1.12,1.12,1.09,1.11,1.12,1.12,1.11,1.12	300	200	1
216	19	4.84	4.84	7.45	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.11,1.19,1.12,1.12,1.12,1.07,1.13,1.13,1.14,1.14,1.13,1.13,1.11,1.19,1.12,1.12,1.12,1.09	300	200	1
301	9	33.90	33.90	16.14	-	300	200	1

302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.72,1.67,1.67,1.66,1.64	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
308	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.72,1.67,1.67,1.66,1.64	300	200	1
311	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.08,1.10,1.11,1.11,1.10,1.11,1.12,1.12,1.13,1.13,1.11,1.11,1.08,1.10,1.11,1.11,1.10,1.11	300	200	1
314	19	4.88	4.00	7.50	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.10,1.33,1.11,1.11,1.11,1.04,1.11,1.11,1.12,1.12,1.11,1.11,1.10,1.31,1.11,1.11,1.11,1.06	300	200	1
315	19	4.84	4.84	7.45	1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.24,1.20,1.17,1.17,1.18,1.18,1.16,1.16,1.15,1.14,1.17,1.17,1.24,1.20,1.17,1.17,1.18,1.18	300	200	1
316	19	4.84	4.84	7.45	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	98.96	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	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	24.70	6.12	40.24	43.62
14	133.20	104.94	23.63	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	377.97	98.96	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	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	24.12	6.12	40.24	43.62
114	133.20	104.94	24.28	6.12	40.24	43.62
115	133.20	93.89	24.78	6.12	40.24	43.62
116	133.20	93.89	24.51	6.12	40.24	43.62
201	377.97	98.96	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	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	24.13	6.12	40.24	43.62
214	133.20	104.94	24.29	6.12	40.24	43.62
215	133.20	93.89	25.02	6.12	40.24	43.62
216	133.20	93.89	24.62	6.12	40.24	43.62
301	377.97	98.96	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	52.83	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	52.83	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	104.94	24.68	6.12	40.24	43.62
314	133.20	104.94	23.73	6.12	40.24	43.62
315	133.20	93.89	26.32	6.12	40.24	43.62
316	133.20	93.89	26.71	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	0.109	0.843	0.003	0.036	0.000	0.887	#13	0.692	Not Required	Pass
2	0.002	0.364	0.189	0.086	0.034	0.502	#21	0.035	Not Required	Pass
3	0.012	0.532	0.081	0.053	0.017	0.619	#21	0.045	Not Required	Pass

4	0.012	0.506	0.169	0.050	0.036	0.626	#21	0.080	Not Required	Pass
5	0.012	0.330	0.175	0.052	0.043	0.369	#21	0.074	Not Required	Pass
6	0.013	0.530	0.086	0.053	0.017	0.615	#21	0.045	Not Required	Pass
7	0.013	0.329	0.173	0.052	0.044	0.372	#21	0.074	Not Required	Pass
8	0.000	0.045	0.117	0.031	0.019	0.162	#21	0.095	Not Required	Pass
9	0.011	0.037	0.048	0.001	0.000	0.086	#21	0.204	Not Required	Pass
10	0.013	0.497	0.171	0.050	0.038	0.628	#21	0.080	Not Required	Pass
11	0.000	0.047	0.115	0.033	0.019	0.162	#21	0.095	Not Required	Pass
12	0.002	0.357	0.187	0.086	0.034	0.488	#21	0.035	Not Required	Pass
13	0.007	0.172	0.433	0.045	0.026	0.592	#21	0.286	Not Required	Pass
14	0.008	0.167	0.433	0.043	0.026	0.586	#21	0.190	Not Required	Pass
15	0.000	0.057	0.201	0.025	0.015	0.259	#21	Not Required	Not Required	Pass
16	0.000	0.055	0.201	0.024	0.015	0.256	#21	Not Required	Not Required	Pass
101	0.114	0.857	0.003	0.036	0.000	0.903	#13	0.692	Not Required	Pass
102	0.002	0.372	0.187	0.090	0.034	0.505	#21	0.035	Not Required	Pass
103	0.013	0.546	0.094	0.054	0.022	0.647	#21	0.045	Not Required	Pass
104	0.013	0.519	0.159	0.052	0.036	0.646	#21	0.080	Not Required	Pass
105	0.013	0.339	0.162	0.054	0.040	0.378	#21	0.074	Not Required	Pass
106	0.013	0.553	0.095	0.055	0.023	0.654	#21	0.045	Not Required	Pass
107	0.013	0.343	0.161	0.054	0.039	0.382	#21	0.074	Not Required	Pass
108	0.001	0.057	0.116	0.030	0.019	0.173	#21	0.095	Not Required	Pass
109	0.007	0.036	0.045	0.001	0.000	0.080	#21	0.204	Not Required	Pass
110	0.013	0.525	0.158	0.052	0.035	0.649	#21	0.080	Not Required	Pass
111	0.000	0.064	0.115	0.032	0.019	0.174	#21	0.095	Not Required	Pass
112	0.001	0.379	0.192	0.090	0.035	0.514	#21	0.035	Not Required	Pass
113	0.007	0.130	0.387	0.043	0.026	0.500	#21	0.286	Not Required	Pass
114	0.008	0.128	0.386	0.041	0.026	0.495	#21	0.286	Not Required	Pass
115	0.000	0.102	0.219	0.031	0.019	0.320	#21	0.346	Not Required	Pass
116	0.000	0.097	0.221	0.029	0.019	0.318	#21	0.346	Not Required	Pass
201	0.114	0.857	0.003	0.036	0.000	0.903	#13	0.692	Not Required	Pass
202	0.001	0.379	0.192	0.090	0.035	0.514	#21	0.035	Not Required	Pass
203	0.013	0.553	0.095	0.055	0.023	0.654	#21	0.045	Not Required	Pass
204	0.013	0.525	0.158	0.052	0.035	0.649	#21	0.080	Not Required	Pass
205	0.013	0.343	0.161	0.054	0.039	0.382	#21	0.074	Not Required	Pass
206	0.013	0.546	0.094	0.054	0.022	0.647	#21	0.045	Not Required	Pass
207	0.013	0.339	0.162	0.054	0.040	0.378	#21	0.074	Not Required	Pass
208	0.000	0.052	0.120	0.029	0.019	0.167	#21	0.095	Not Required	Pass
209	0.007	0.036	0.045	0.001	0.000	0.080	#21	0.204	Not Required	Pass
210	0.013	0.519	0.159	0.052	0.036	0.646	#21	0.080	Not Required	Pass
211	0.000	0.057	0.119	0.031	0.019	0.168	#21	0.095	Not Required	Pass
212	0.002	0.372	0.187	0.090	0.034	0.505	#21	0.035	Not Required	Pass
213	0.007	0.130	0.387	0.043	0.026	0.500	#21	0.286	Not Required	Pass
214	0.008	0.128	0.386	0.041	0.026	0.495	#21	0.286	Not Required	Pass
215	0.001	0.117	0.219	0.032	0.019	0.331	#21	0.346	Not Required	Pass
216	0.001	0.108	0.220	0.030	0.019	0.329	#21	0.346	Not Required	Pass
301	0.109	0.843	0.003	0.036	0.000	0.887	#13	0.692	Not Required	Pass
302	0.002	0.357	0.187	0.086	0.034	0.488	#21	0.035	Not Required	Pass
303	0.013	0.530	0.086	0.053	0.017	0.615	#21	0.045	Not Required	Pass
304	0.013	0.497	0.171	0.050	0.038	0.628	#21	0.080	Not Required	Pass
305	0.013	0.329	0.173	0.052	0.044	0.372	#21	0.074	Not Required	Pass
306	0.012	0.532	0.081	0.053	0.017	0.619	#21	0.045	Not Required	Pass
307	0.012	0.330	0.175	0.052	0.043	0.369	#21	0.074	Not Required	Pass
308	0.000	0.055	0.201	0.024	0.015	0.256	#21	Not Required	Not Required	Pass
309	0.011	0.037	0.048	0.001	0.000	0.086	#21	0.204	Not Required	Pass

309	0.011	0.057	0.048	0.001	0.000	0.080	#21	0.204	Not Required	Pass
310	0.012	0.506	0.169	0.050	0.036	0.626	#21	0.080	Not Required	Pass
311	0.000	0.057	0.201	0.025	0.015	0.259	#21	Not Required	Not Required	Pass
312	0.002	0.364	0.189	0.086	0.034	0.502	#21	0.035	Not Required	Pass
313	0.007	0.172	0.433	0.045	0.026	0.592	#21	0.190	Not Required	Pass
314	0.008	0.167	0.433	0.043	0.026	0.586	#21	0.286	Not Required	Pass
315	0.000	0.100	0.219	0.033	0.019	0.317	#21	0.346	Not Required	Pass
316	0.000	0.094	0.221	0.031	0.019	0.315	#21	0.346	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/comresssion)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

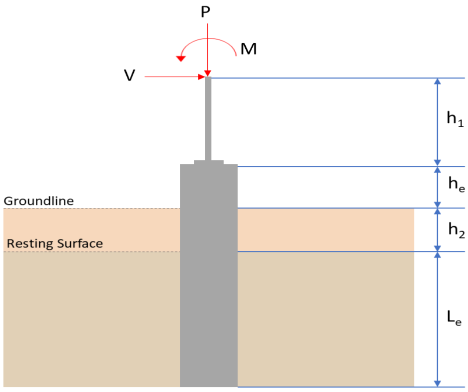
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.892	10.771
V_x (kip)	-2.415	-4.031
V_z (kip)	-0.012	-0.020
M_x (kipft)	-0.056	-0.099
M_z (kipft)	40.840	70.223

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.415\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.38455\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.84\ \text{kipft}) + ((-2.415\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.5032\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.0915\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.012\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0019108\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056\ \text{kipft}) + ((-0.012\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0089172\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.8509\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.0915\ \text{ft}), (0.8509\ \text{ft})]$$

$$L_{e,req} = 7.092\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.092\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.9456$$

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

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

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

$$q = \frac{(6.892\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.43075\ \text{kip/ft}^2$$

$q = 0.43075 \text{ kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.43075 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.21537$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.38455 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5032 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5032 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (6.5032 \text{ kipft/ft})) + (4 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1426 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5032 \text{ kipft/ft})) + (3 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]^{\,2}}{(7.5 \text{ ft})^2 \times [(3 \times (6.5032 \text{ kipft/ft})) + (2 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.29243 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5032 \text{ kipft/ft})) + ((-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0797 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1426 \text{ ft})}{2}$$

$$p_a = 0.3857 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29243 \text{ kip/ft}^2\right)}{\left(0.3857 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.75819$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0797\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95974$$

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

Considering z-direction:

$H_o = -0.0019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0089172\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0089172\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.0089172\ \mathrm{kipft/ft})) + (4 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3233\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0089172\ \mathrm{kipft/ft})) + (3 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.0089172\ \mathrm{kipft/ft})) + (2 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.00037438\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0089172\ \mathrm{kipft/ft})) + ((-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.00037367\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3233\ \mathrm{ft})}{2}$$

$$p_a = 0.39925\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00037438\ \mathrm{kip/ft^2}\right)}{\left(0.39925\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00093772$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

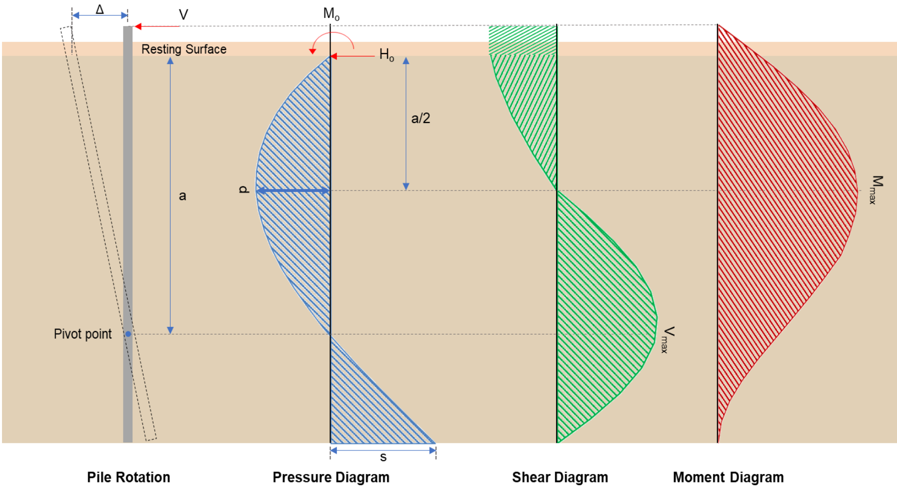
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00037367\ \text{kip/ft}^2)}{(1.125\ \text{kip/ft}^2)}$$

$$Ratio = 0.00033215$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.031\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.64188\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70.223\ \text{kipft}) + ((-4.031\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 11.182\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.182\ \text{kipft/ft})}{(-0.64188\ \text{kip/ft})}$$

$$E = 17.421\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.182\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.64188\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (11.182\ \text{kipft/ft})) + (4 \times (-0.64188\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1394\ \text{ft}$$

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

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

$$V_{max} = ((-0.64188\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.421\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1394\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.421\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1394\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.251\ \text{kip}$$

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

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

$$M_{max} = ((-0.64188\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.5\ \mathrm{ft})) \times \left[\left(\frac{(17.421\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + \frac{(5.1394\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right) - \left[\left(\frac{4 \times (17.421\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3 \right) \times \left(\frac{(5.1394\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (17.421\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2 \right) \times \left(\frac{(5.1394\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right)^4 \right] \right]$$

$$M_{max} = 44.186\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.02\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0031847\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.099\ \mathrm{kipft}) + ((-0.02\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

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

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015764\ \mathrm{kipft/ft})}{(-0.0031847\ \mathrm{kip/ft})}$$

$$E = 4.95\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015764\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.0031847\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.015764\ \mathrm{kipft/ft})) + (4 \times (-0.0031847\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3141\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0031847\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.95\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3 \right) \times \left(\frac{(5.3141\ \mathrm{ft})}{(7.5\ \mathrm{ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.95\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2 \right) \times \left(\frac{(5.3141\ \mathrm{ft})}{(7.5\ \mathrm{ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.023331\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.0031847\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.5\ \mathrm{ft})) \times \left[\left(\frac{(4.95\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + \frac{(5.3141\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right) - \left[\left(\frac{4 \times (4.95\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3 \right) \times \left(\frac{(5.3141\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.95\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2 \right) \times \left(\frac{(5.3141\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.078935 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.771 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.238 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.238 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.771\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0040263$$	Status: **PASS** Ratio: **0.000**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.771\ \text{kip} \rightarrow 10771\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10771\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 119.92\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (119.92\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 119.92\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.92\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.03\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 12.251\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.251\ \mathrm{kip})}{(111.03\ \mathrm{kip})}$$

$$Ratio = 0.11034$$

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

Considering z-direction:

$V_{max} = 0.023331\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.023331\ \mathrm{kip})}{(111.03\ \mathrm{kip})}$$

$$Ratio = 0.00021013$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 44.186 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(44.186 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.17703$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.078935 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.078935 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00031625$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

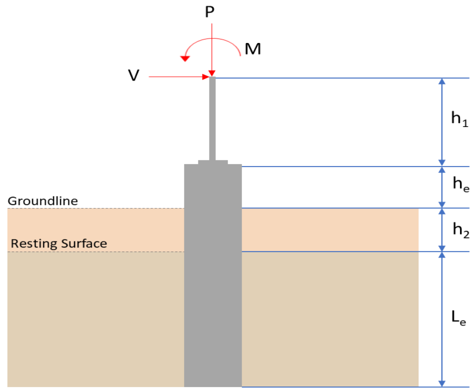
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.197	11.272
V_x (kip)	-2.459	-4.103
V_z (kip)	0.012	0.021
M_x (kipft)	0.061	0.107
M_z (kipft)	41.556	71.345

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.459\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.39156\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.556 \text{ kipft}) + ((-2.459 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6172 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.1266 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.012 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0019108 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.061 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.96078 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.1266 \text{ ft}), (0.96078 \text{ ft})]$$

$$L_{e,req} = 7.127 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.127 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.95027$$

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

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

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

$$q = \frac{(7.197 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.44981 \text{ kip/ft}^2$$

$$q = 0.44981\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.44981\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.22491$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.39156\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.6172\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.6172\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.39156\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.6172\ \mathrm{kipft/ft})) + (4 \times (-0.39156\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1427\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.6172\ \mathrm{kipft/ft})) + (3 \times (-0.39156\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.6172\ \mathrm{kipft/ft})) + (2 \times (-0.39156\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.29744\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.6172\ \mathrm{kipft/ft})) + ((-0.39156\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0984\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1427\ \mathrm{ft})}{2}$$

$$p_a = 0.3857\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.29744\ \mathrm{kip/ft^2})}{(0.3857\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.77117$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0984\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97637$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.0019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0097134\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0097134\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.0097134\ \mathrm{kipft/ft})) + (4 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3099\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0097134\ \mathrm{kipft/ft})) + (3 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.0097134\ \mathrm{kipft/ft})) + (2 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0015452\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0097134\ \mathrm{kipft/ft})) + ((0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.0036008\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3099\ \mathrm{ft})}{2}$$

$$p_a = 0.39824\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0015452\ \mathrm{kip/ft^2}\right)}{\left(0.39824\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0038802$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

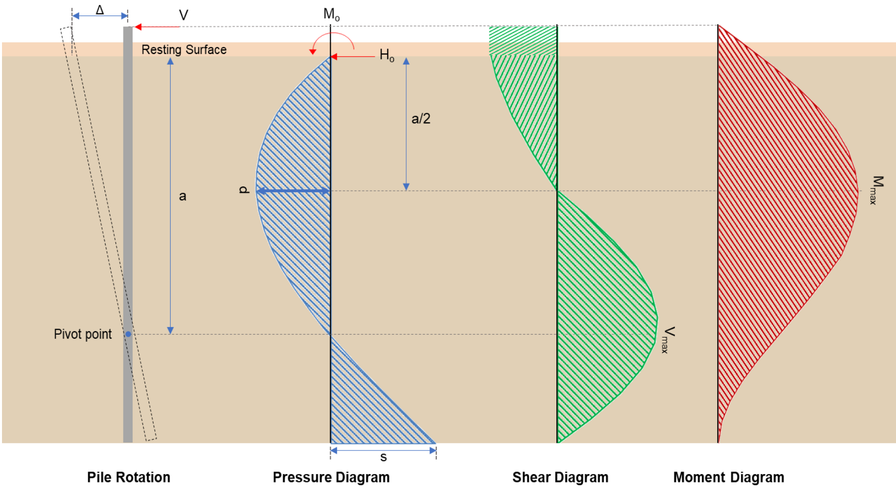
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0036008\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0032008$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.103\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.65334\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(71.345\ \mathrm{kipft}) + ((-4.103\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.361\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.361\ \mathrm{kipft/ft})}{(-0.65334\ \mathrm{kip/ft})}$$

$$E = 17.388\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.361\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.65334\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (11.361\ \mathrm{kipft/ft})) + (4 \times (-0.65334\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1396\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.65334\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.388\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1396\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.388\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1396\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.45\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.65334 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(17.388 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (17.388 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (17.388 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 44.901 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.021 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0033439 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.107 \text{ kipft}) + ((0.021 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.017038 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.017038 \text{ kipft/ft})}{(0.0033439 \text{ kip/ft})}$$

$$E = 5.0952 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.017038 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (0.0033439 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.017038 \text{ kipft/ft})) + (4 \times (0.0033439 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3096 \text{ ft}$$

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

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

$$V_{max} = ((0.0033439 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.0952 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.3096 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.0952 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.3096 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.024952 \text{ kip}$$

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

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

$$M_{max} = ((0.0033439 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(5.0952 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3096 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.0952 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.3096 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.0952 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.3096 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.084584 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.272 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.222 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.222 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.272\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0042135$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.272\ \text{kip} \rightarrow 11272\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11272\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,		
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a)		

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.07\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.45\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.45\ \text{kip})}{(111.07\ \text{kip})}$$

$$Ratio = 0.11209$$

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

Considering z-direction:

$V_{max} = 0.024952\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.024952\ \text{kip})}{(111.07\ \text{kip})}$$

$$Ratio = 0.00022465$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 44.901\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(44.901\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.17989$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.084584\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.084584\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00033888$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

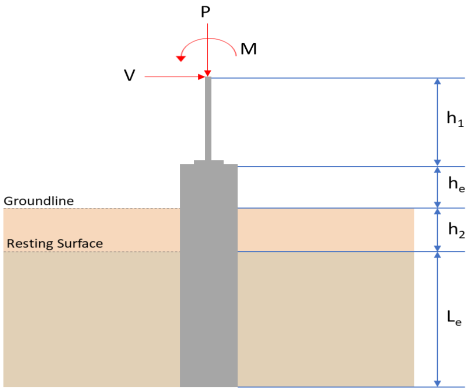
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.197	11.272
V_x (kip)	-2.459	-4.103
V_z (kip)	-0.012	-0.021
M_x (kipft)	-0.061	-0.108
M_z (kipft)	41.556	71.346

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,

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

$$H_o = \frac{(-2.459\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.39156\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.556\ \text{kipft}) + ((-2.459\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.6172\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.1266\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.012\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0019108\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.061\ \text{kipft}) + ((-0.012\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.87773\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.1266\ \text{ft}), (0.87773\ \text{ft})]$$

$$L_{e,req} = 7.127\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.127\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.95027$$

Status: PASS
Ratio: 0.950

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

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

$$q = \frac{(7.197\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.44981\ \text{kip/ft}^2$$

$$q = 0.44981 \text{ kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.44981 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.22491$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.39156 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.6172 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.6172 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.39156 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (6.6172 \text{ kipft/ft})) + (4 \times (-0.39156 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1427 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.6172 \text{ kipft/ft})) + (3 \times (-0.39156 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.6172 \text{ kipft/ft})) + (2 \times (-0.39156 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.29744 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.6172 \text{ kipft/ft})) + ((-0.39156 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0984 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1427 \text{ ft})}{2}$$

$$p_a = 0.3857 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29744 \text{ kip/ft}^2\right)}{\left(0.3857 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.77117$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0984\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97637$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = -0.0019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0097134\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0097134\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.0097134\ \mathrm{kipft/ft})) + (4 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3099\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0097134\ \mathrm{kipft/ft})) + (3 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.0097134\ \mathrm{kipft/ft})) + (2 \times (-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.00047841\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0097134\ \mathrm{kipft/ft})) + ((-0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.00054352\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3099\ \mathrm{ft})}{2}$$

$$p_a = 0.39824\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00047841\ \mathrm{kip/ft^2}\right)}{\left(0.39824\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0012013$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

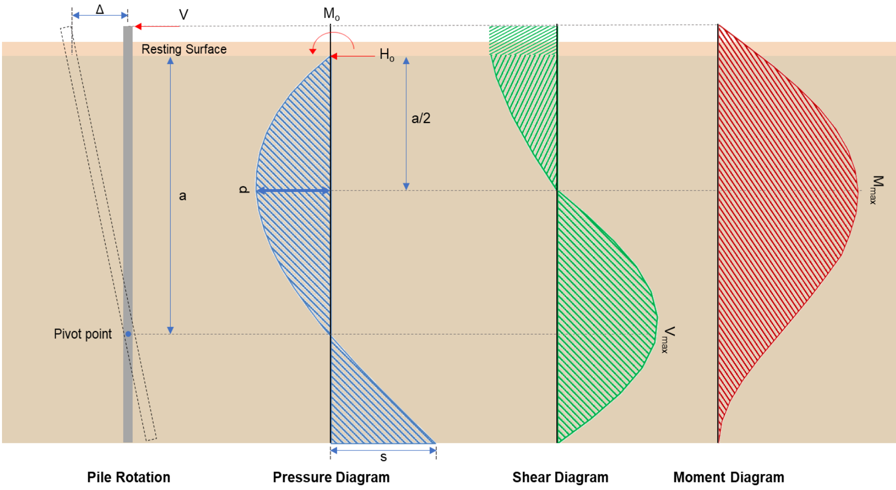
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00054352\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00048313$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.103\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.65334\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(71.346\ \mathrm{kipft}) + ((-4.103\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.361\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.361\ \mathrm{kipft/ft})}{(-0.65334\ \mathrm{kip/ft})}$$

$$E = 17.389\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.361\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.65334\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (11.361\ \mathrm{kipft/ft})) + (4 \times (-0.65334\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1396\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.65334\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.389\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1396\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.389\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1396\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.45\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.65334 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(17.389 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (17.389 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (17.389 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.1396 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 44.901 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.021 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0033439 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.108 \text{ kipft}) + ((-0.021 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.017197 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.017197 \text{ kipft/ft})}{(-0.0033439 \text{ kip/ft})}$$

$$E = 5.1429 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.017197 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.0033439 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.017197 \text{ kipft/ft})) + (4 \times (-0.0033439 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3081 \text{ ft}$$

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

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

$$V_{max} = ((-0.0033439 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1429 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3081 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.1429 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3081 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.025101 \text{ kip}$$

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

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

$$M_{max} = ((-0.0033439 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(5.1429 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3081 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.1429 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3081 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.1429 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3081 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.085142 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.272 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.222 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.222 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.272\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0042135$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 11.272\ \mathrm{kip} \rightarrow 11272\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11272\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 120\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (120\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 120\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.07\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.45\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.45\ \text{kip})}{(111.07\ \text{kip})}$$

$$Ratio = 0.11209$$

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

Considering z-direction:

$V_{max} = 0.025101\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.025101\ \text{kip})}{(111.07\ \text{kip})}$$

$$Ratio = 0.00022599$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 44.901 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(44.901 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.17989$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.085142 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.085142 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00034111$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

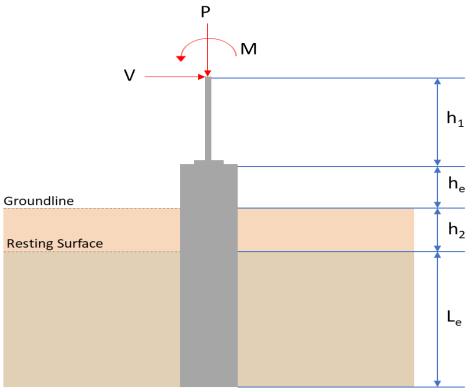
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.892	10.771
V_x (kip)	-2.415	-4.031
V_z (kip)	0.012	0.020
M_x (kipft)	0.056	0.099
M_z (kipft)	40.840	70.224

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.415\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.38455\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.84 \text{ kipft}) + ((-2.415 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.5032 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.0915 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.012 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0019108 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0089172 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.93633 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.0915 \text{ ft}), (0.93633 \text{ ft})]$$

$$L_{e,req} = 7.092 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.092 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.9456$$

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

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

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

$$q = \frac{(6.892 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.43075 \text{ kip/ft}^2$$

$q = 0.43075 \text{ kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.43075 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.21537$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.38455 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5032 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5032 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (6.5032 \text{ kipft/ft})) + (4 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1426 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5032 \text{ kipft/ft})) + (3 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.5032 \text{ kipft/ft})) + (2 \times (-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.29243 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5032 \text{ kipft/ft})) + ((-0.38455 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0797 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1426 \text{ ft})}{2}$$

$$p_a = 0.3857 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.29243 \text{ kip/ft}^2)}{(0.3857 \text{ kip/ft}^2)}$$

$$Ratio = 0.75819$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.0797\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.95974$$

Status: PASS
Ratio: 0.960

Considering z-direction:

$H_o = 0.0019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0089172\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0089172\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.0089172\ \mathrm{kipft/ft})) + (4 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3233\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0089172\ \mathrm{kipft/ft})) + (3 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.0089172\ \mathrm{kipft/ft})) + (2 \times (0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0014889\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0089172\ \mathrm{kipft/ft})) + ((0.0019108\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.003431\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3233\ \mathrm{ft})}{2}$$

$$p_a = 0.39925\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0014889\ \mathrm{kip/ft^2})}{(0.39925\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0037292$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

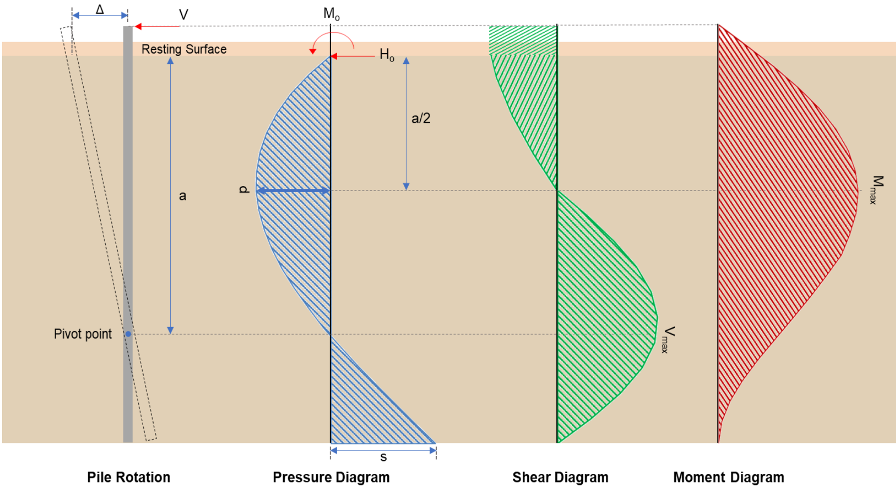
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.003431\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0030498$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.031\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.64188\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70.224\ \mathrm{kipft}) + ((-4.031\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.182\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.182\ \mathrm{kipft/ft})}{(-0.64188\ \mathrm{kip/ft})}$$

$$E = 17.421\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.182\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.64188\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (11.182\ \mathrm{kipft/ft})) + (4 \times (-0.64188\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1394\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.64188\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.421\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1394\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (17.421\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1394\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.251\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.64188\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(17.421\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.1394\ \text{ft})}{2 \times (7.5\ \text{ft})} \right) - \left[\left(\frac{4 \times (17.421\ \text{ft})}{(7.5\ \text{ft})} + 3 \right) \times \left(\frac{(5.1394\ \text{ft})}{2 \times (7.5\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (17.421\ \text{ft})}{(7.5\ \text{ft})} + 2 \right) \times \left(\frac{(5.1394\ \text{ft})}{2 \times (7.5\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 44.187\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.02\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0031847\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.099\ \text{kipft}) + ((0.02\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

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

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015764\ \text{kipft/ft})}{(0.0031847\ \text{kip/ft})}$$

$$E = 4.95\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015764\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (0.0031847\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.015764\ \text{kipft/ft})) + (4 \times (0.0031847\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.3141\ \text{ft}$$

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

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

$$V_{max} = ((0.0031847\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.95\ \text{ft})}{(7.5\ \text{ft})} + 3 \right) \times \left(\frac{(5.3141\ \text{ft})}{(7.5\ \text{ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.95\ \text{ft})}{(7.5\ \text{ft})} + 2 \right) \times \left(\frac{(5.3141\ \text{ft})}{(7.5\ \text{ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.023331\ \text{kip}$$

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

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

$$M_{max} = ((0.0031847\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(4.95\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.3141\ \text{ft})}{2 \times (7.5\ \text{ft})} \right) - \left[\left(\frac{4 \times (4.95\ \text{ft})}{(7.5\ \text{ft})} + 3 \right) \times \left(\frac{(5.3141\ \text{ft})}{2 \times (7.5\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.95\ \text{ft})}{(7.5\ \text{ft})} + 2 \right) \times \left(\frac{(5.3141\ \text{ft})}{2 \times (7.5\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.078935 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.771 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.238 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.238 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.771\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0040263$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 10.771\ \mathrm{kip} \rightarrow 10771\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(10771\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.92\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.92\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.92\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.92\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.03\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 12.251\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.251\ \mathrm{kip})}{(111.03\ \mathrm{kip})}$$

$$Ratio = 0.11034$$

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

Considering z-direction:

$V_{max} = 0.023331\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.023331\ \mathrm{kip})}{(111.03\ \mathrm{kip})}$$

$$Ratio = 0.00021013$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 44.187\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(44.187\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.17703$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.078935\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.078935\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00031625$$	Status: **PASS** Ratio: **0.000**