Project Details

Project Name: TOP50-44x95-105|40-FixedCarport - V1Jb

Location: Charlo, MT 59824, USA

Unique ID: 4P-19.75-8TOP-XD-72-L-5Hx10W-STRUTS-E6K6

Dealer: ______________________________

Date: Tue Dec 17 2024

Number of Modules: 50

Number of Poles: 4

Date Sold:

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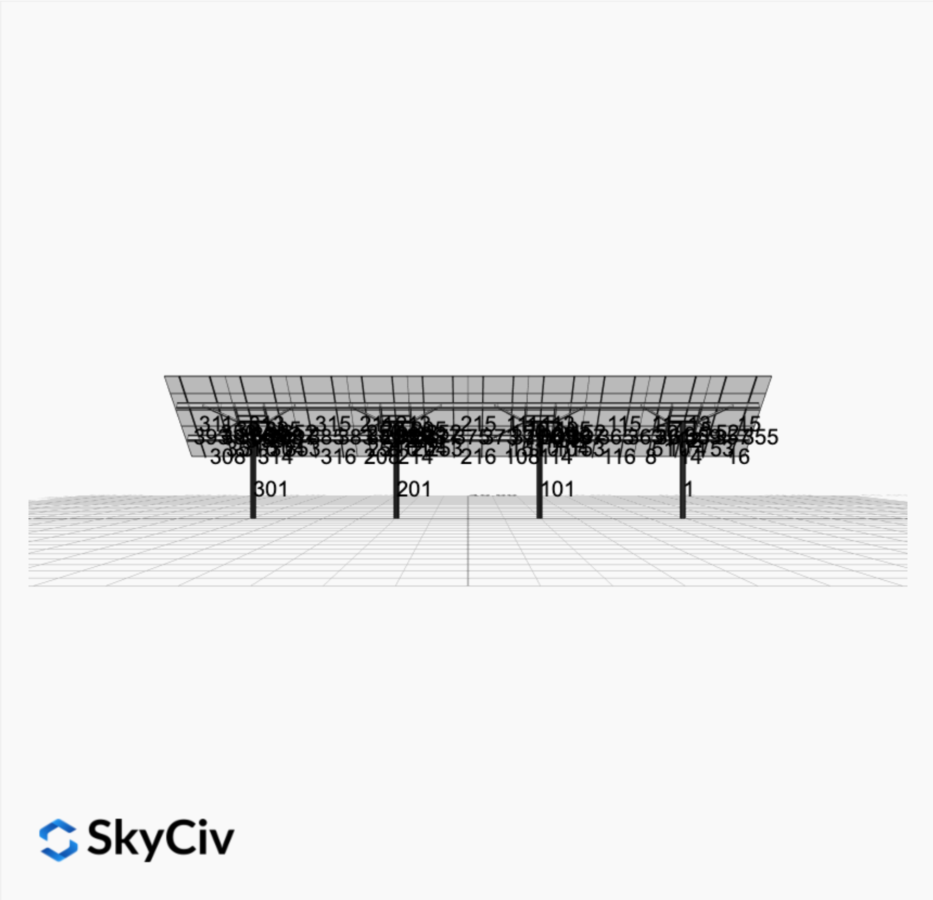

Array Dimensions N/S	18.54 ft
Array Dimensions E/W	80.00 ft
Winter Tilt Angle	35
Front Edge Clearance	8 ft

MT Solar Bill of Materials (4P-19.75-8TOP-XD-72-L-5Hx10W-STRUTS-E6K6)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-72	72IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	10

Rail Bill of Materials

Part	Qty
Rails (220in)	20

Part	Qty
Rail Attachment	80
Module Mid Clamp	80
Module End Clamp	40
Ground Lug	10

Site Details:

Site Address: Charlo, MT 59824, USA

Array Specification

Duty Classification:	XD
Module Width:	44.00 in
Module Length:	95.00in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Winter Tilt Angle:	35
Front Edge Clearance:	8
Total Array Height at Tilt:	18.64 ft
Total Frame Length:	78.75 ft
Frame Weight:	6621 lbs
Array Dimensions N/S:	18.54 ft
Array Dimensions E/W:	80.00 ft
Rail Length:	222.50 in
Rail Spacing:	4.00 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	13.32 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 8.25 ft Pile 2: 8.25 ft Pile 3: 8.25 ft Pile 4: 8.25 ft
Foundation Volume:	19.556 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Charlo, MT 59824, USA
Wind Speed:	105 mph

Snow Load:	40 psf

Design Disclaimer

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

AutoDesigner Input


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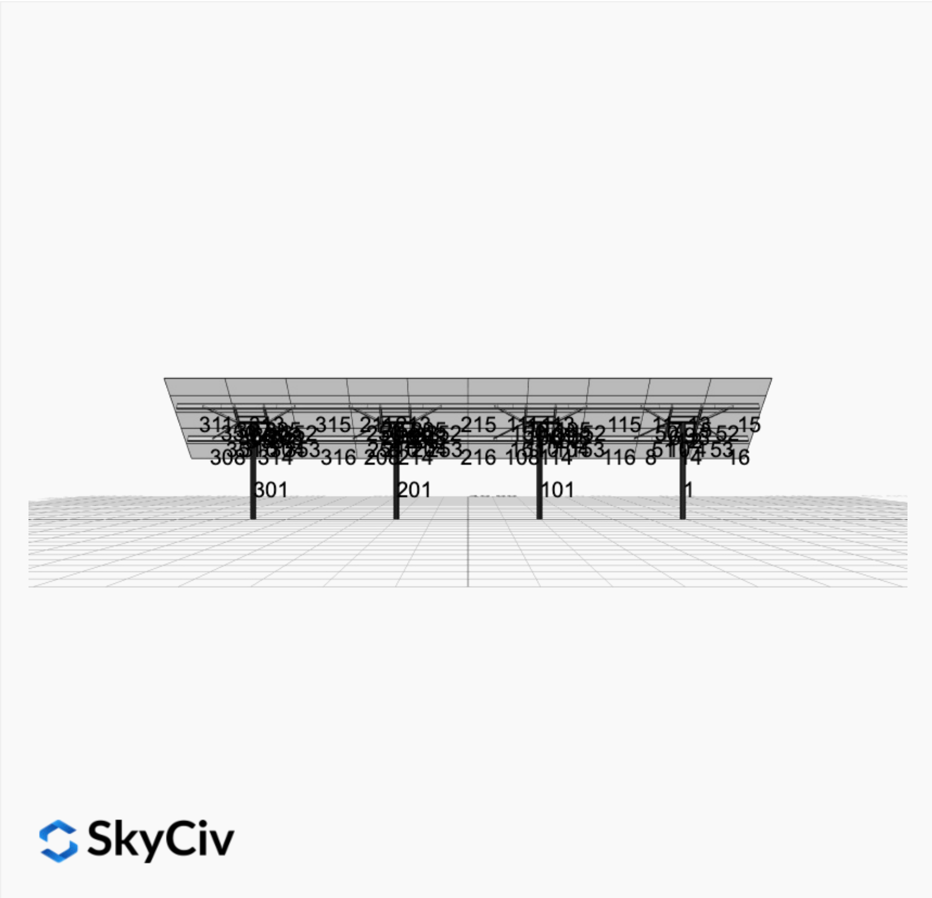
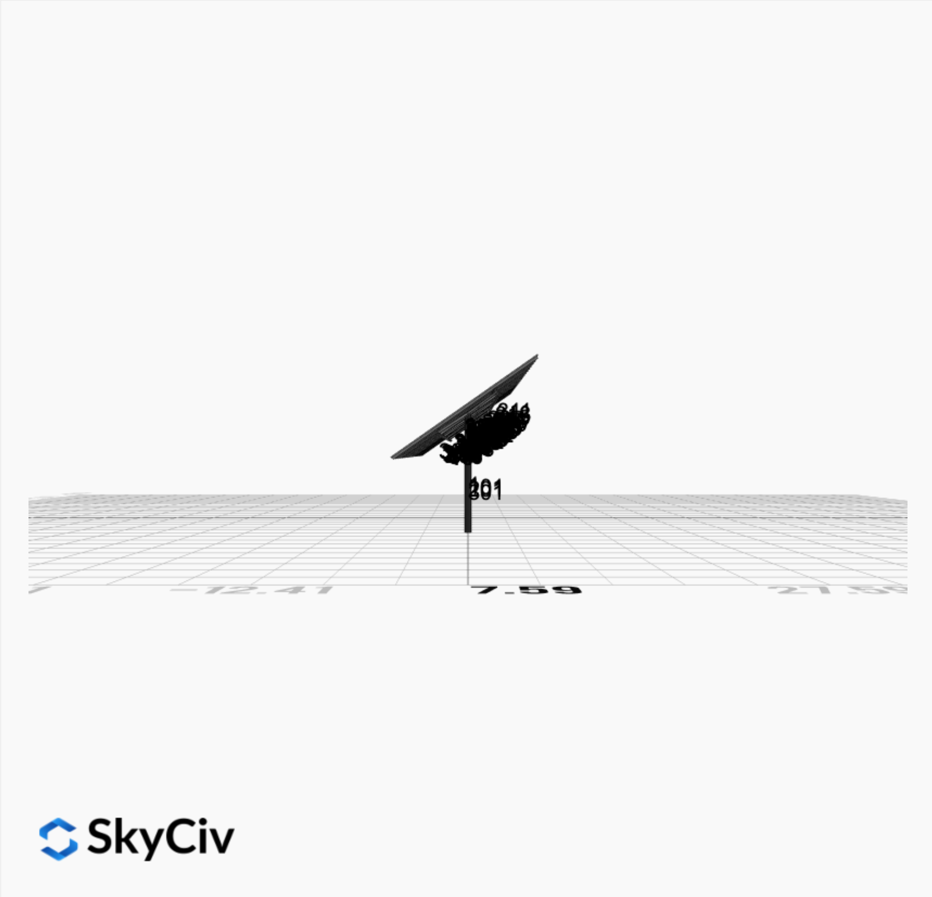
Design Notes:

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

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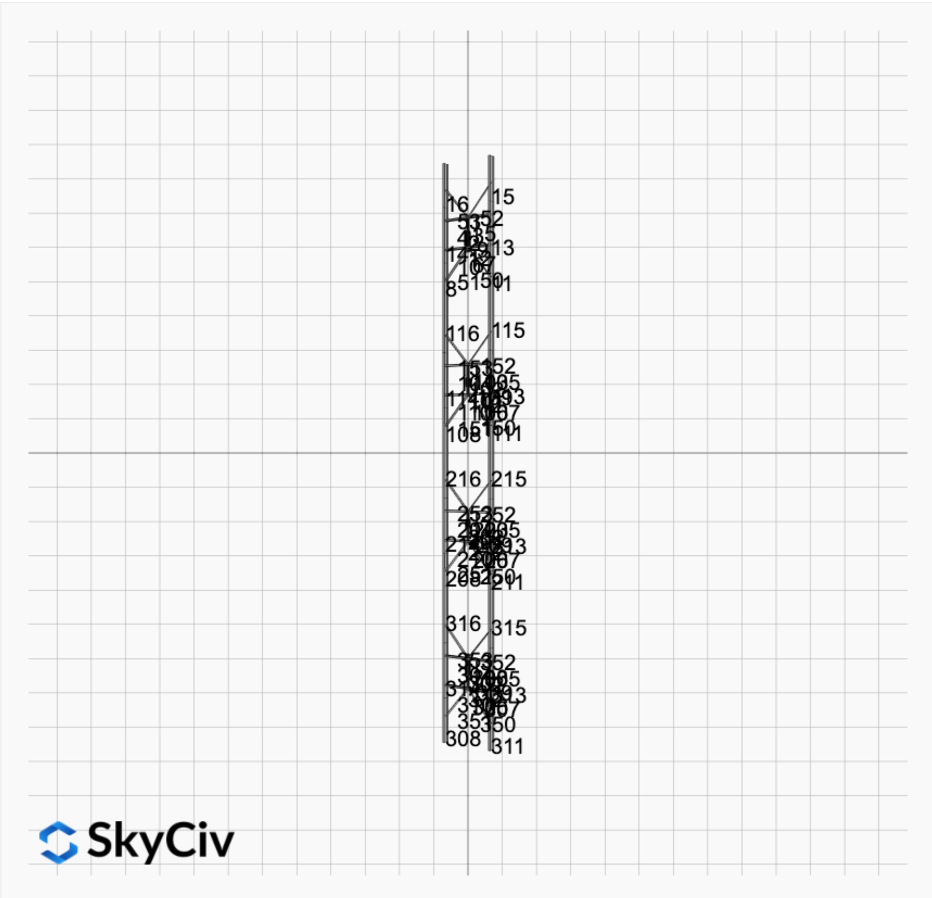
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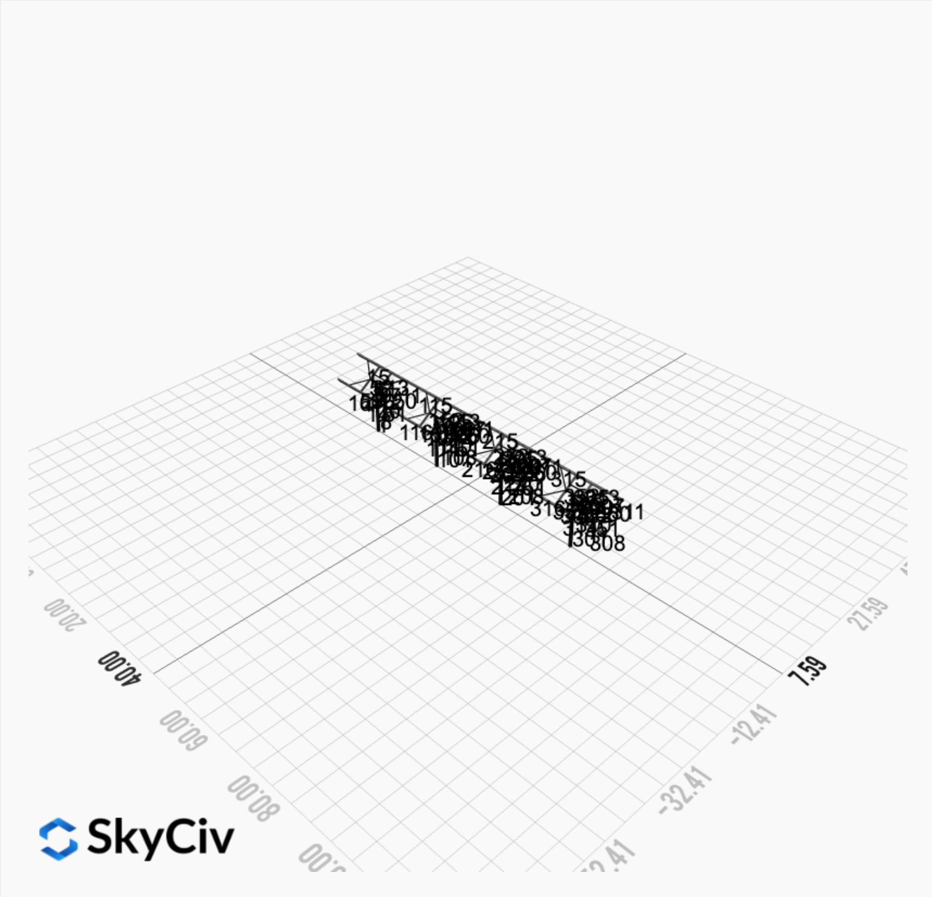
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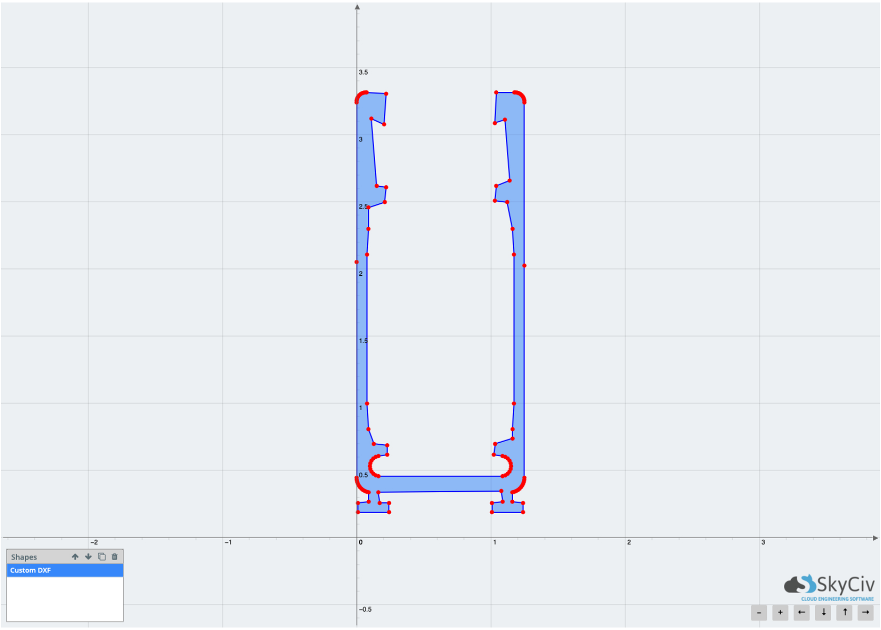
40.00
60.00
80.00
27.59
7.59
-12.41
-32.41

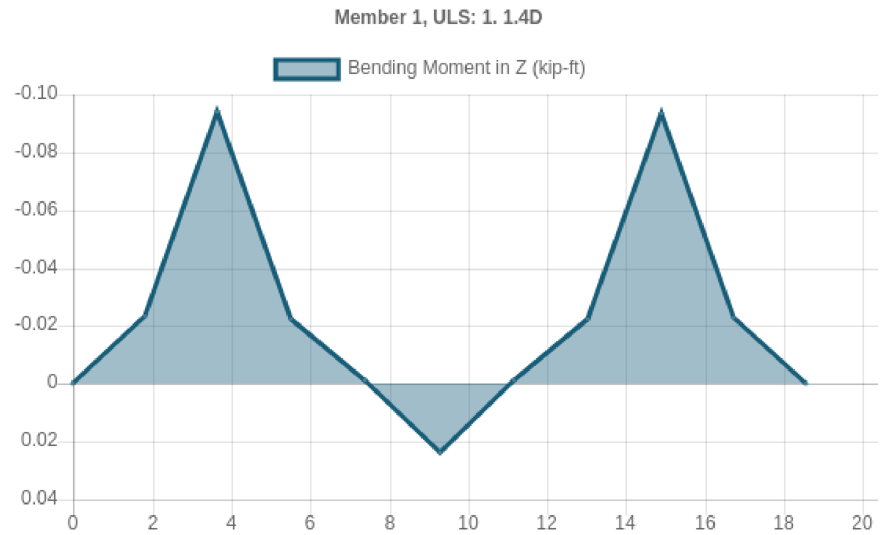

301
201
101
1

Rail Design Check

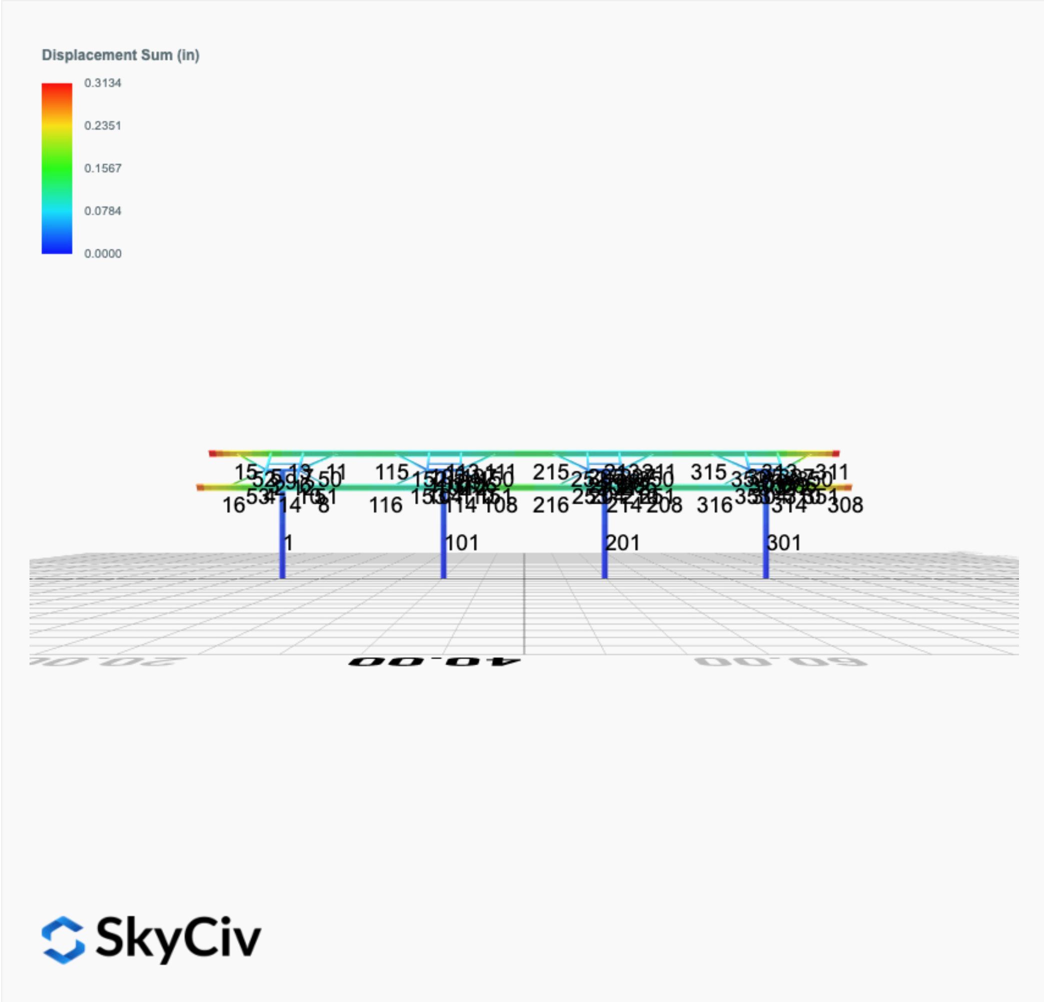
Rail Length: 18.541666666666668 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 4 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0504 kip/ft
Snow (Y): -0.0353 kip/ft
Wind uplift Case A: 0.1121 kip/ft
Wind uplift Case A: 0.1121 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.1515 kip/ft

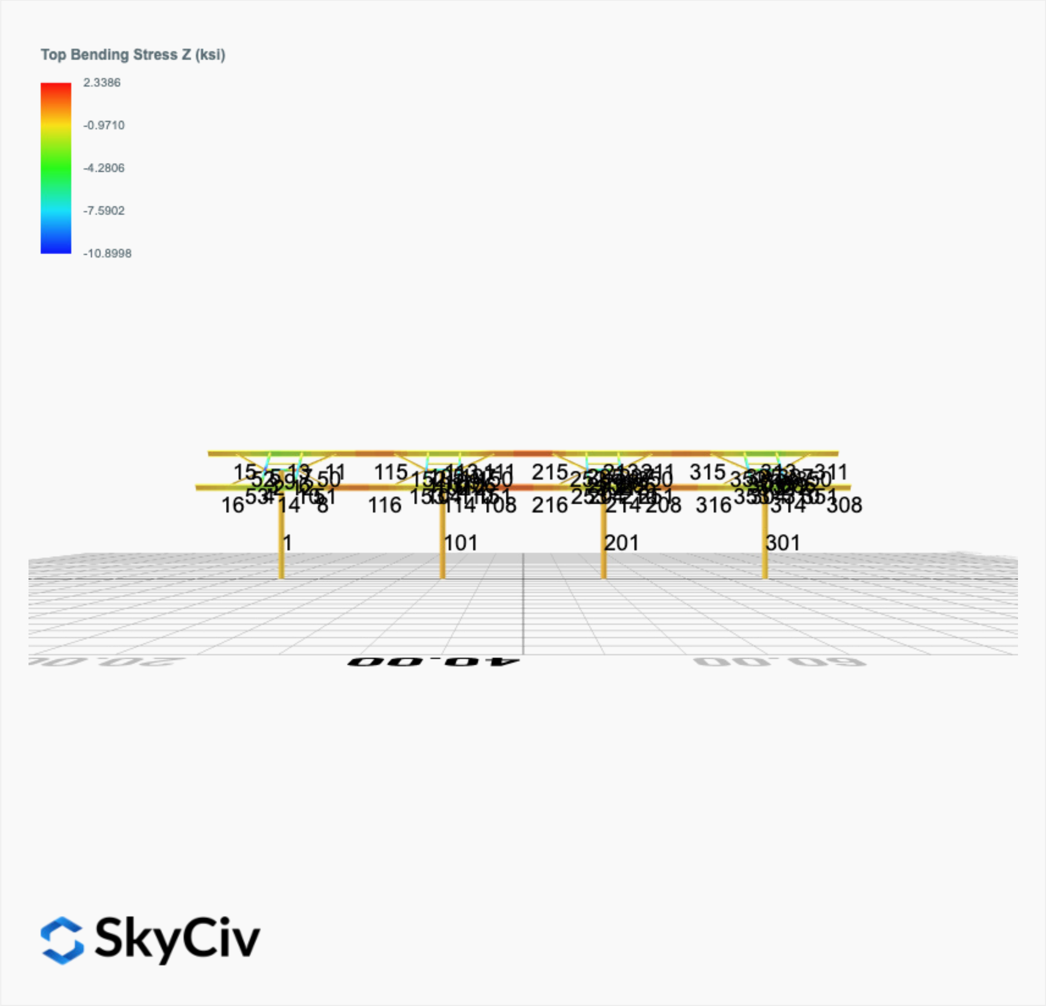


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	23.6975852	0.687	PASS
Material Yield	34.5	23.6975852	0.687	PASS
Material Strength	37	23.6975852	0.640	PASS



FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
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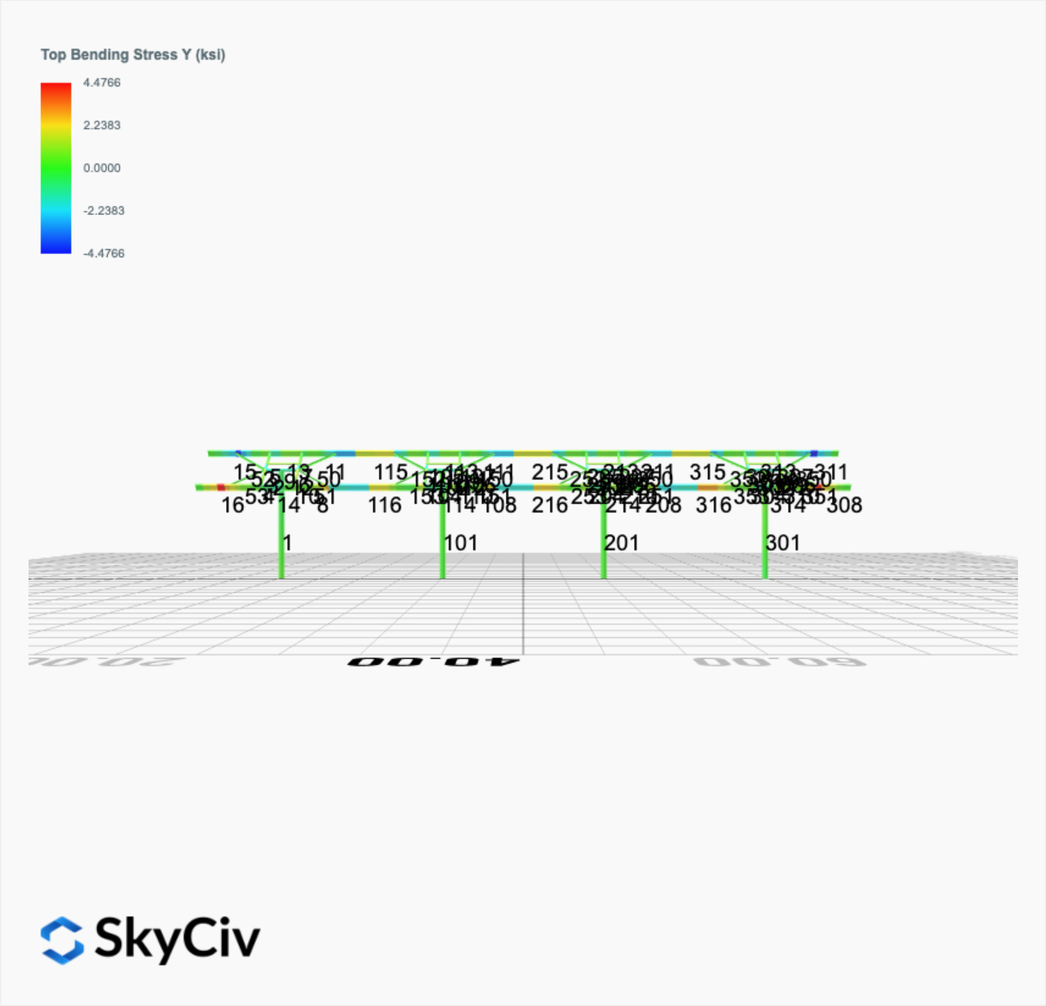
-0.9710
-4.2806
-7.5902
-10.8998
SkyCiv


Top Bending Stress Y (ksi)
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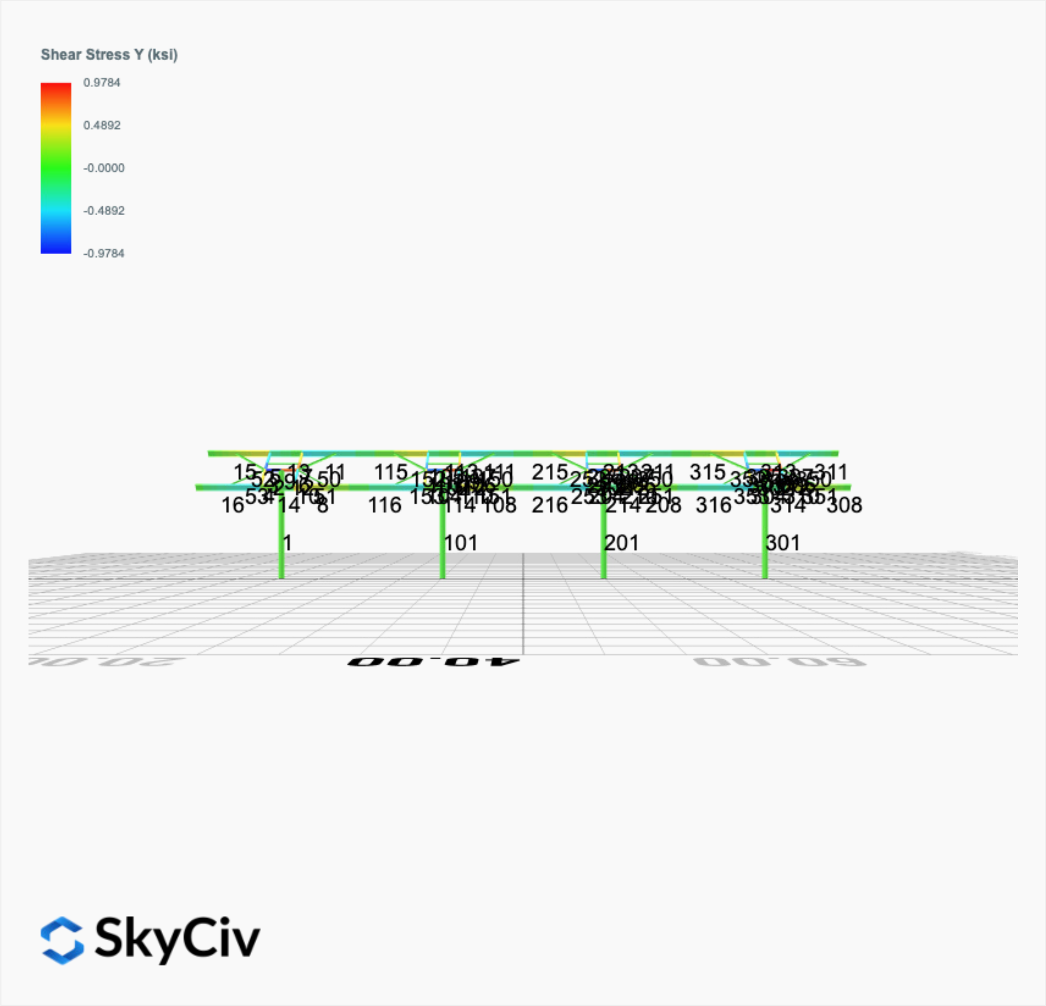
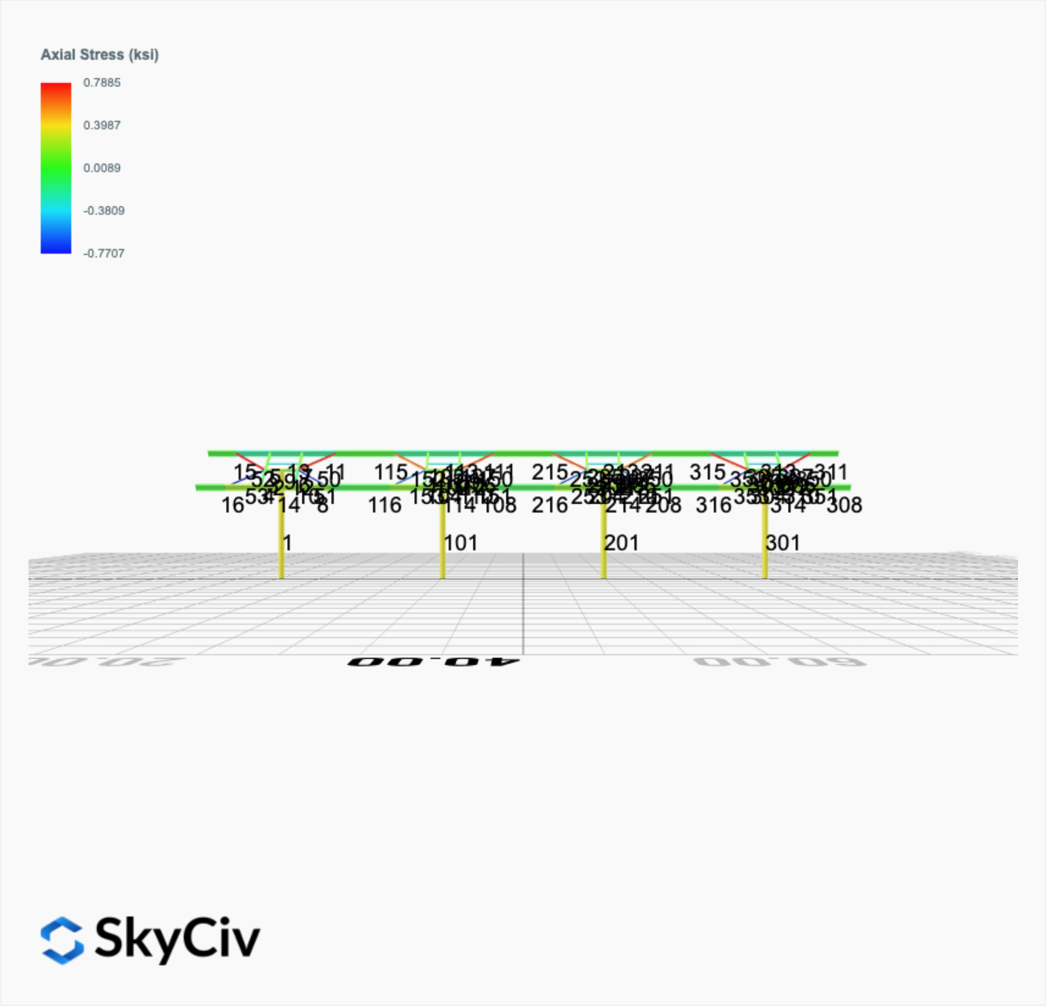
-2.2383
-4.4766
1
101
201
301
SkyCiv


Shear Stress Y (ksi)
0.9784
0.4892
-0.0000
-0.4892
-0.9784
1
101
201
301
SkyCiv


Axial Stress (ksi)
0.7885
0.3987
0.0089
-0.3809
-0.7707

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	-0.0177	3.0708	-0.0366	-0.1439	0.1209	0.2524
ULS: 2. D + L	-0.0177	3.0708	-0.0366	-0.1439	0.1209	0.2524
ULS: 3. D + (S or Lr or R)	-0.0552	7.7664	-0.1147	-0.4507	0.3789	0.7534
ULS: 3. D + (S or Lr or R)	-0.0177	3.0708	-0.0366	-0.1439	0.1209	0.2524
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0459	6.5925	-0.0952	-0.3740	0.3144	0.6282
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0177	3.0708	-0.0366	-0.1439	0.1209	0.2524
ULS: 5b. D + 0.7E	-0.0177	3.0708	-0.0366	-0.1439	0.1209	0.2524
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0459	6.5925	-0.0952	-0.3740	0.3144	0.6282
ULS: 8. 0.6D + 0.7E	-0.0106	1.8425	-0.0220	-0.0863	0.0726	0.1514
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.3217	9.3070	-0.1883	-0.7431	0.6386	59.6806
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.3217	9.3070	-0.1883	-0.7431	0.6386	59.6806
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.6193	-2.1915	0.0897	0.3529	-0.3103	-46.9908
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.0002	-1.3180	0.0731	0.2879	-0.2594	-51.1200
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2738	11.2697	-0.2089	-0.8234	0.7026	45.1993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.2738	11.2697	-0.2089	-0.8234	0.7026	45.1993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6819	2.6458	-0.0005	-0.0014	-0.0090	-34.8043
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2176	3.3009	-0.0129	-0.0501	0.0292	-37.9012
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2457	7.7480	-0.1504	-0.5933	0.5092	44.8235
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.2457	7.7480	-0.1504	-0.5933	0.5092	44.8235
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.7100	-0.8759	0.0581	0.2287	-0.2025	-35.1800
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2457	-0.2208	0.0457	0.1800	-0.1643	-38.2769
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.3146	8.0787	-0.1736	-0.6855	0.5902	59.5796
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.3146	8.0787	-0.1736	-0.6855	0.5902	59.5796
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.6264	-3.4199	0.1043	0.4105	-0.3586	-47.0918
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.0073	-2.5463	0.0878	0.3455	-0.3077	-51.2210

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	16.4290
Shear X	-7.2105
Shear Z	-0.3392
Moment X	-1.3407
Moment Y (Twist)	1.1485
Moment Z	101.4699

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	11.2697
Shear X	-4.3217
Shear Z	-0.2089
Moment X	-0.8234
Moment Y (Twist)	0.7026
Moment Z	59.6806

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	0.0177	2.9839	0.0056	0.0214	-0.0166	-0.1922
ULS: 2. D + L	0.0177	2.9839	0.0056	0.0214	-0.0166	-0.1922
ULS: 3. D + (S or Lr or R)	0.0552	7.4952	0.0176	0.0668	-0.0518	-0.6420
ULS: 3. D + (S or Lr or R)	0.0177	2.9839	0.0056	0.0214	-0.0166	-0.1922
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0459	6.3674	0.0146	0.0555	-0.0430	-0.5295

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0177	2.9839	0.0056	0.0214	-0.0166	-0.1922
ULS: 5b. D + 0.7E	0.0177	2.9839	0.0056	0.0214	-0.0166	-0.1922
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0459	6.3674	0.0146	0.0555	-0.0430	-0.5295
ULS: 8. 0.6D + 0.7E	0.0106	1.7904	0.0034	0.0128	-0.0100	-0.1153
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1532	8.8512	0.0305	0.1167	-0.0760	57.4212
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.1532	8.8512	0.0305	0.1167	-0.0760	57.4212
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.5315	-1.9660	-0.0160	-0.0614	0.0376	-45.9901
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.9588	-1.1375	-0.0105	-0.0399	0.0168	-50.1934
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0824	10.7679	0.0333	0.1270	-0.0876	42.6805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0824	10.7679	0.0333	0.1270	-0.0876	42.6805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6812	2.6549	-0.0016	-0.0066	-0.0023	-34.8779
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2516	3.2763	0.0025	0.0095	-0.0179	-38.0305
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1105	7.3844	0.0243	0.0929	-0.0612	43.0178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1105	7.3844	0.0243	0.0929	-0.0612	43.0178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6530	-0.7285	-0.0106	-0.0407	0.0240	-34.5406
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2235	-0.1071	-0.0064	-0.0246	0.0084	-37.6931
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1603	7.6577	0.0283	0.1082	-0.0694	57.4980
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.1603	7.6577	0.0283	0.1082	-0.0694	57.4980
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.5244	-3.1596	-0.0183	-0.0700	0.0442	-45.9132
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.9517	-2.3311	-0.0127	-0.0485	0.0234	-50.1166

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	15.6851
Shear X	-6.9516
Shear Z	0.0542
Moment X	0.2070
Moment Y (Twist)	0.1342
Moment Z	97.3499

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.7679
Shear X	-4.1603
Shear Z	0.0333
Moment X	0.1270
Moment Y (Twist)	0.0876
Moment Z	57.4980

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	0.0177	2.9839	-0.0056	-0.0214	0.0166	-0.1922
ULS: 2. D + L	0.0177	2.9839	-0.0056	-0.0214	0.0166	-0.1922
ULS: 3. D + (S or Lr or R)	0.0552	7.4952	-0.0176	-0.0668	0.0518	-0.6420
ULS: 3. D + (S or Lr or R)	0.0177	2.9839	-0.0056	-0.0214	0.0166	-0.1922
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0459	6.3674	-0.0146	-0.0555	0.0430	-0.5295
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0177	2.9839	-0.0056	-0.0214	0.0166	-0.1922
ULS: 5b. D + 0.7E	0.0177	2.9839	-0.0056	-0.0214	0.0166	-0.1922
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0459	6.3674	-0.0146	-0.0555	0.0430	-0.5295
ULS: 8. 0.6D + 0.7E	0.0106	1.7904	-0.0034	-0.0128	0.0100	-0.1153
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.1532	8.8512	-0.0305	-0.1167	0.0760	57.4212
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.1532	8.8512	-0.0305	-0.1167	0.0760	57.4212
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.5315	-1.9660	0.0160	0.0614	-0.0376	-45.9901
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.9588	-1.1375	0.0105	0.0400	-0.0168	-50.1934

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0824	10.7679	-0.0333	-0.1270	0.0876	42.6805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0824	10.7679	-0.0333	-0.1270	0.0876	42.6805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6812	2.6549	0.0016	0.0066	0.0024	-34.8779
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2516	3.2763	-0.0025	-0.0095	0.0180	-38.0305
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1105	7.3844	-0.0243	-0.0929	0.0612	43.0178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1105	7.3844	-0.0243	-0.0929	0.0612	43.0178
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6530	-0.7285	0.0106	0.0407	-0.0240	-34.5406
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2235	-0.1071	0.0064	0.0246	-0.0084	-37.6931
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.1603	7.6577	-0.0283	-0.1082	0.0694	57.4980
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.1603	7.6577	-0.0283	-0.1082	0.0694	57.4980
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.5244	-3.1596	0.0183	0.0700	-0.0442	-45.9132
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.9517	-2.3311	0.0127	0.0485	-0.0234	-50.1166

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	15.6850
Shear X	-6.9516
Shear Z	-0.0542
Moment X	-0.2073
Moment Y (Twist)	0.1346
Moment Z	97.3501

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.7679
Shear X	-4.1603
Shear Z	-0.0333
Moment X	-0.1270
Moment Y (Twist)	0.0876
Moment Z	57.4980

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	-0.0177	3.0708	0.0366	0.1439	-0.1209	0.2524
ULS: 2. D + L	-0.0177	3.0708	0.0366	0.1439	-0.1209	0.2524
ULS: 3. D + (S or Lr or R)	-0.0552	7.7664	0.1147	0.4507	-0.3789	0.7534
ULS: 3. D + (S or Lr or R)	-0.0177	3.0708	0.0366	0.1439	-0.1209	0.2524
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0459	6.5925	0.0952	0.3740	-0.3144	0.6282
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0177	3.0708	0.0366	0.1439	-0.1209	0.2524
ULS: 5b. D + 0.7E	-0.0177	3.0708	0.0366	0.1439	-0.1209	0.2524
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0459	6.5925	0.0952	0.3740	-0.3144	0.6282
ULS: 8. 0.6D + 0.7E	-0.0106	1.8425	0.0220	0.0863	-0.0726	0.1514
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.3217	9.3071	0.1883	0.7431	-0.6386	59.6806
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.3217	9.3071	0.1883	0.7431	-0.6386	59.6806
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.6193	-2.1915	-0.0897	-0.3529	0.3103	-46.9908
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.0002	-1.3180	-0.0731	-0.2879	0.2594	-51.1200
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2739	11.2697	0.2089	0.8234	-0.7026	45.1993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.2739	11.2697	0.2089	0.8234	-0.7026	45.1993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6819	2.6458	0.0005	0.0014	0.0090	-34.8043
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2176	3.3009	0.0129	0.0501	-0.0292	-37.9012
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2457	7.7480	0.1504	0.5933	-0.5092	44.8235
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.2457	7.7480	0.1504	0.5933	-0.5092	44.8235
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.7100	-0.8759	-0.0581	-0.2287	0.2025	-35.1800
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2457	-0.2208	-0.0457	-0.1800	0.1643	-38.2769

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.3146	8.0787	0.1736	0.6855	-0.5902	59.5796
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.3146	8.0787	0.1736	0.6855	-0.5902	59.5796
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.6264	-3.4199	-0.1043	-0.4105	0.3587	-47.0918
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.0073	-2.5463	-0.0878	-0.3455	0.3077	-51.2210

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	16.4291
Shear X	-7.2104
Shear Z	0.3392
Moment X	1.3407
Moment Y (Twist)	1.1481
Moment Z	101.4704

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	11.2697
Shear X	-4.3217
Shear Z	0.2089
Moment X	0.8234
Moment Y (Twist)	0.7026
Moment Z	59.6806

Project Details

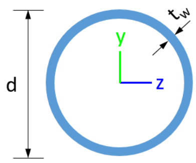
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	TOP50-44x95-105|40-FixedCarport - V1Jb
Unit System:	imperial

Design Input Information

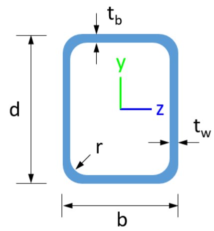
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

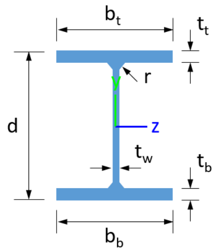
Section Dimensions



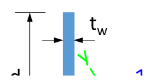
ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
10	8in Pipe Sch 80	8.63	0.50					

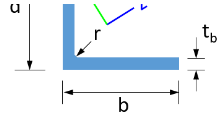


ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		



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





ID	Name	d (in)	t_w (in)	b (in)	t_b (in)	r (in)		
34	L3x2x3/16	3.00	0.19	2.00	0.19	0.31		

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60
34	L3x2x3/16	0.92	0.01	0.17	0.98	0.01	0.33	0.82

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	27.97	27.97	13.32	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
4	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.77,1.76,1.77,1.76,1.77,1.77,1.76,1.76,1.76,1.97,1.76,1.76,1.76,1.69,1.76,1.76,1.77,1.77,1.76,1.76,1.75,1.91,1.76,1.76,1.76,1.71	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
11	20	1.33	1.33	2.05	1.79,1.79,1.79,1.79,1.79,1.79,1.79,1.79,1.78,1.78,1.79,1.79,1.78,1.78,1.79,1.79,1.79,1.78,1.79,1.79,1.77,1.78,1.79,1.79,1.78,1.78	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.11,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.11,1.08,1.08,1.08,1.09	300	200	1
14	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,3.43,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.07,1.08,1.08,1.08,2.01,1.08,1.08,1.08,1.11	300	200	1
15	20	6.00	6.00	6.00	2.32,2.32,2.32,2.31,2.32,2.32,2.31,2.31,2.31,2.31,2.31,2.31,2.31,2.31,2.32,2.32,2.30,2.25,2.31,2.31,2.30,2.31,2.31,2.31,2.31,2.31	300	200	1
16	20	6.00	6.00	6.00	2.32,2.32,2.32,2.31,2.32,2.32,2.31,2.31,2.31,2.22,2.31,2.31,2.31,2.32,2.31,2.31,2.30,2.30,2.31,2.31,2.30,2.33,2.31,2.31,2.31,2.31	300	200	1
50	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
51	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
52	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
53	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
101	10	27.97	27.97	13.32	-	300	200	1

102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
108	20	1.33	1.33	2.05	1.95,1.95,1.95,1.95,1.95,1.95,1.95,1.95,1.96,1.72,1.95,1.95,1.96,1.47,1.96,1.96,1.95,2.05,1.95,1.95,1.97,2.24,1.95,1.95,1.96,1.55	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
111	20	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.07,2.06,2.06,2.06,2.07,2.06,2.06,2.06,1.69,2.06,2.06,2.06,2.07,2.06,2.06,2.06,2.07	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.04,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06	300	200	1
114	20	4.88	4.00	7.50	1.05,1.06,1.05,1.06,1.05,1.05,1.06,1.06,1.06,3.71,1.06,1.06,1.06,1.03,1.06,1.06,1.06,1.06,1.06,1.06,2.12,1.06,1.06,1.06,1.04	300	200	1
115	20	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18	300	200	1
116	20	10.20	10.20	10.20	1.17,1.18,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.66,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.23,1.18,1.18,1.18,1.16	300	200	1
150	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
151	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
152	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
153	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
201	10	27.97	27.97	13.32	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,1.68,2.08,2.08,2.08,1.61,2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.03,2.08,2.08,2.08,1.78	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
211	20	1.33	1.33	2.05	2.18,2.20,2.18,2.22,2.19,2.18,2.23,2.23,2.17,2.37,2.22,2.22,2.18,2.34,2.23,2.23,2.25,2.05,2.21,2.21,2.19,2.39,2.22,2.22,2.17,2.33	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.04,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06	300	200	1
214	20	4.88	4.00	7.50	1.05,1.06,1.05,1.06,1.05,1.05,1.06,1.06,1.06,3.71,1.06,1.06,1.06,1.03,1.06,1.06,1.06,1.06,1.06,1.06,2.12,1.06,1.06,1.06,1.04	300	200	1
215	20	10.20	10.20	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12	300	200	1

216	20	10.20	10.20	10.20	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.67,1.11,1.11,1.11,1.09,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.18,1.11,1.11,1.11,1.09	300	200	1
250	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
251	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
252	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
253	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
301	10	27.97	27.97	13.32	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
308	20	6.00	6.00	6.00	2.32,2.32,2.32,2.31,2.32,2.32,2.31,2.31,2.31,2.22,2.31,2.31,2.31,2.32,2.31,2.31,2.30,2.30,2.31,2.31,2.30,2.33,2.31,2.31,2.31,2.31	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65	300	200	1
311	20	6.00	6.00	6.00	2.33,2.32,2.32,2.31,2.32,2.32,2.31,2.31,2.31,2.31,2.31,2.31,2.31,2.31,2.32,2.32,2.30,2.25,2.31,2.31,2.30,2.31,2.31,2.31,2.31,2.31	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.11,1.08,1.08,1.08,1.09	300	200	1
314	20	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,3.39,1.08,1.08,1.08,1.13,1.08,1.08,1.08,1.07,1.08,1.08,2.00,1.08,1.08,1.08,1.11	300	200	1
315	20	10.20	10.20	10.20	1.37,1.37,1.37,1.38,1.37,1.37,1.38,1.38,1.39,1.39,1.38,1.38,1.38,1.39,1.38,1.38,1.37,1.33,1.38,1.38,1.39,1.39,1.38,1.38,1.38,1.39	300	200	1
316	20	10.20	10.20	10.20	1.39,1.39,1.39,1.39,1.39,1.39,1.40,1.40,1.40,1.35,1.40,1.40,1.40,1.40,1.40,1.40,1.38,1.39,1.40,1.40,1.40,1.36,1.40,1.40,1.40,1.39	300	200	1
350	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
351	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
352	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250
353	34	5.67	5.67	5.67	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14	300	200	250

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	574.32	212.05	123.94	123.94	172.30	172.30
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91

9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	33.00	6.46	56.26	44.91
14	159.30	97.43	32.84	6.46	56.26	44.91
15	159.30	86.08	46.90	6.46	56.26	44.91
16	159.30	86.08	46.90	6.46	56.26	44.91
50	41.27	8.45	1.63	0.88	15.23	10.15
51	41.27	8.45	1.63	0.88	15.23	10.15
52	41.27	8.45	1.63	0.88	15.23	10.15
53	41.27	8.45	1.63	0.88	15.23	10.15
101	574.32	212.05	123.94	123.94	172.30	172.30
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.64	6.46	56.26	44.91
114	159.30	97.43	31.48	6.46	56.26	44.91
115	159.30	32.87	22.69	6.46	56.26	44.91
116	159.30	32.87	22.27	6.46	56.26	44.91
150	41.27	8.45	1.63	0.88	15.23	10.15
151	41.27	8.45	1.63	0.88	15.23	10.15
152	41.27	8.45	1.63	0.88	15.23	10.15
153	41.27	8.45	1.63	0.88	15.23	10.15
201	574.32	212.05	123.94	123.94	172.30	172.30
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.67	6.46	56.26	44.91
214	159.30	97.43	31.55	6.46	56.26	44.91
215	159.30	32.87	21.35	6.46	56.26	44.91
216	159.30	32.87	20.91	6.46	56.26	44.91
250	41.27	8.45	1.63	0.88	15.23	10.15
251	41.27	8.45	1.63	0.88	15.23	10.15
252	41.27	8.45	1.63	0.88	15.23	10.15
253	41.27	8.45	1.63	0.88	15.23	10.15

301	574.32	212.05	123.94	123.94	172.30	172.30
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	86.08	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	86.08	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	33.00	6.46	56.26	44.91
314	159.30	97.43	32.84	6.46	56.26	44.91
315	159.30	32.87	25.60	6.46	56.26	44.91
316	159.30	32.87	26.02	6.46	56.26	44.91
350	41.27	8.45	1.63	0.88	15.23	10.15
351	41.27	8.45	1.63	0.88	15.23	10.15
352	41.27	8.45	1.63	0.88	15.23	10.15
353	41.27	8.45	1.63	0.88	15.23	10.15

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	0.077	0.819	0.026	0.042	0.002	0.868	#13	0.583	Not Required	Pass
2	0.005	0.557	0.280	0.112	0.052	0.838	#13	0.054	Not Required	Pass
3	0.003	0.852	0.112	0.086	0.045	0.914	#13	0.046	Not Required	Pass
4	0.004	0.829	0.033	0.083	0.004	0.834	#13	0.082	Not Required	Pass
5	0.003	0.528	0.020	0.085	0.008	0.539	#13	0.076	Not Required	Pass
6	0.003	0.738	0.110	0.073	0.046	0.793	#13	0.046	Not Required	Pass
7	0.003	0.459	0.022	0.073	0.007	0.472	#13	0.076	Not Required	Pass
8	0.007	0.103	0.086	0.049	0.009	0.110	#13	0.102	Not Required	Pass
9	0.020	0.097	0.062	0.003	0.001	0.165	#13	0.137	Not Required	Pass
10	0.003	0.724	0.062	0.072	0.010	0.768	#13	0.122	Not Required	Pass
11	0.007	0.102	0.077	0.050	0.009	0.104	#13	0.068	Not Required	Pass
12	0.005	0.440	0.238	0.098	0.044	0.679	#13	0.054	Not Required	Pass
13	0.007	0.395	0.030	0.063	0.007	0.414	#13	0.204	Not Required	Pass
14	0.013	0.394	0.049	0.062	0.009	0.441	#13	0.306	Not Required	Pass
15	0.007	0.162	0.137	0.045	0.012	0.188	#21	0.306	Not Required	Pass
16	0.013	0.158	0.137	0.044	0.011	0.190	#21	0.306	Not Required	Pass
50	0.187	0.010	0.001	0.002	0.001	0.197	#21	0.783	Not Required	Pass
51	0.039	0.006	0.014	0.002	0.002	0.054	#21	0.522	Not Required	Pass
52	0.186	0.010	0.001	0.003	0.001	0.195	#23	0.783	Not Required	Pass
53	0.037	0.006	0.014	0.002	0.002	0.053	#23	0.522	Not Required	Pass
101	0.074	0.785	0.004	0.040	0.000	0.824	#13	0.583	Not Required	Pass
102	0.004	0.456	0.240	0.098	0.046	0.697	#13	0.054	Not Required	Pass
103	0.004	0.751	0.106	0.075	0.043	0.801	#13	0.046	Not Required	Pass
104	0.004	0.724	0.045	0.072	0.007	0.751	#13	0.082	Not Required	Pass
105	0.004	0.466	0.019	0.074	0.005	0.477	#13	0.076	Not Required	Pass
106	0.003	0.766	0.107	0.077	0.043	0.821	#13	0.046	Not Required	Pass
107	0.003	0.475	0.017	0.076	0.005	0.482	#13	0.076	Not Required	Pass

108	0.007	0.069	0.055	0.045	0.007	0.117	#21	0.102	Not Required	Pass
109	0.019	0.065	0.049	0.001	0.000	0.118	#13	0.137	Not Required	Pass
110	0.004	0.744	0.042	0.074	0.006	0.763	#13	0.082	Not Required	Pass
111	0.007	0.064	0.055	0.046	0.008	0.114	#21	0.068	Not Required	Pass
112	0.004	0.474	0.245	0.101	0.046	0.721	#13	0.054	Not Required	Pass
113	0.007	0.237	0.037	0.059	0.007	0.260	#13	0.204	Not Required	Pass
114	0.012	0.225	0.043	0.057	0.007	0.235	#13	0.306	Not Required	Pass
115	0.007	0.195	0.107	0.042	0.013	0.232	#13	0.520	Not Required	Pass
116	0.032	0.197	0.116	0.040	0.013	0.236	#21	0.780	Not Required	Pass
150	0.168	0.010	0.001	0.002	0.001	0.177	#21	0.783	Not Required	Pass
151	0.033	0.006	0.014	0.002	0.002	0.049	#23	0.522	Not Required	Pass
152	0.163	0.010	0.001	0.002	0.001	0.173	#24	0.783	Not Required	Pass
153	0.032	0.006	0.014	0.002	0.002	0.048	#24	0.522	Not Required	Pass
201	0.074	0.785	0.004	0.040	0.000	0.824	#13	0.583	Not Required	Pass
202	0.004	0.474	0.245	0.101	0.046	0.721	#13	0.054	Not Required	Pass
203	0.003	0.766	0.107	0.077	0.043	0.821	#13	0.046	Not Required	Pass
204	0.004	0.744	0.042	0.074	0.006	0.763	#13	0.082	Not Required	Pass
205	0.003	0.475	0.017	0.076	0.005	0.482	#13	0.076	Not Required	Pass
206	0.004	0.751	0.106	0.075	0.043	0.801	#13	0.046	Not Required	Pass
207	0.004	0.466	0.019	0.074	0.005	0.477	#13	0.076	Not Required	Pass
208	0.007	0.044	0.048	0.040	0.007	0.068	#24	0.102	Not Required	Pass
209	0.019	0.065	0.049	0.001	0.000	0.118	#13	0.137	Not Required	Pass
210	0.004	0.724	0.045	0.072	0.007	0.751	#13	0.082	Not Required	Pass
211	0.007	0.044	0.049	0.042	0.007	0.068	#21	0.068	Not Required	Pass
212	0.004	0.456	0.240	0.098	0.046	0.697	#13	0.054	Not Required	Pass
213	0.007	0.237	0.037	0.059	0.007	0.260	#13	0.204	Not Required	Pass
214	0.012	0.225	0.043	0.057	0.007	0.235	#13	0.306	Not Required	Pass
215	0.007	0.288	0.081	0.046	0.012	0.315	#13	0.520	Not Required	Pass
216	0.030	0.296	0.079	0.045	0.012	0.323	#13	0.780	Not Required	Pass
250	0.163	0.010	0.001	0.002	0.001	0.173	#24	0.783	Not Required	Pass
251	0.032	0.006	0.014	0.002	0.002	0.048	#24	0.522	Not Required	Pass
252	0.168	0.010	0.001	0.002	0.001	0.177	#21	0.783	Not Required	Pass
253	0.033	0.006	0.014	0.002	0.002	0.049	#23	0.522	Not Required	Pass
301	0.077	0.819	0.026	0.042	0.002	0.868	#13	0.583	Not Required	Pass
302	0.005	0.440	0.238	0.098	0.044	0.679	#13	0.054	Not Required	Pass
303	0.003	0.738	0.110	0.073	0.046	0.793	#13	0.046	Not Required	Pass
304	0.003	0.724	0.062	0.072	0.010	0.768	#13	0.122	Not Required	Pass
305	0.003	0.459	0.022	0.073	0.007	0.472	#13	0.076	Not Required	Pass
306	0.003	0.852	0.112	0.086	0.045	0.914	#13	0.046	Not Required	Pass
307	0.003	0.528	0.020	0.084	0.008	0.539	#13	0.076	Not Required	Pass
308	0.013	0.158	0.137	0.044	0.011	0.190	#21	0.459	Not Required	Pass
309	0.020	0.097	0.062	0.003	0.001	0.165	#13	0.137	Not Required	Pass
310	0.004	0.829	0.033	0.083	0.004	0.834	#13	0.082	Not Required	Pass
311	0.007	0.162	0.137	0.045	0.012	0.188	#21	0.306	Not Required	Pass
312	0.005	0.557	0.280	0.112	0.052	0.838	#13	0.054	Not Required	Pass
313	0.007	0.395	0.030	0.063	0.007	0.414	#13	0.204	Not Required	Pass
314	0.013	0.394	0.049	0.062	0.009	0.441	#13	0.306	Not Required	Pass
315	0.007	0.180	0.107	0.050	0.013	0.207	#21	0.520	Not Required	Pass
316	0.032	0.179	0.116	0.049	0.013	0.209	#21	0.780	Not Required	Pass
350	0.186	0.010	0.001	0.003	0.001	0.195	#23	0.783	Not Required	Pass
351	0.037	0.006	0.014	0.002	0.002	0.053	#23	0.522	Not Required	Pass

352	0.187	0.010	0.001	0.002	0.001	0.197	#21	0.783	Not Required	Pass
353	0.039	0.006	0.014	0.002	0.002	0.054	#21	0.522	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

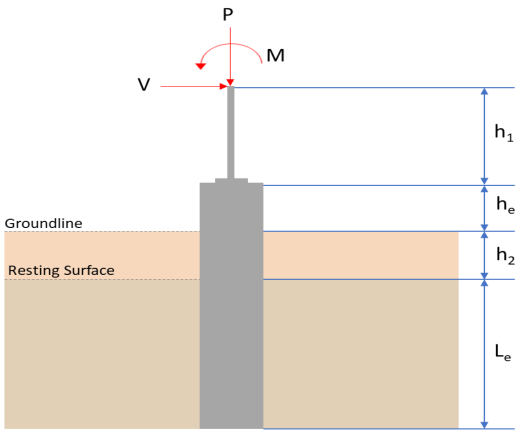
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 8.25 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.270	16.429
V_x (kip)	-4.322	-7.211
V_z (kip)	-0.209	-0.339
M_x (kipft)	-0.823	-1.341
M_z (kipft)	59.681	101.470

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,

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

$$H_o = \frac{(-4.322 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.68822 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.681\ \text{kipft}) + ((-4.322\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 9.5033\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6347\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.209\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.03328\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.823\ \text{kipft}) + ((-0.209\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.13105\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.8868\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.6347\ \text{ft}), (1.8868\ \text{ft})]$$

$$L_{e,req} = 7.635\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.635\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.92545$$

Status: **PASS**
Ratio: **0.930**

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

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

$$q = \frac{(11.27\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.70438\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.70438\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.35219$$

Status: **PASS**
Ratio: **0.350**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.68822\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.5033\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.5033\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (9.5033\ \text{kipft/ft})) + (4 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6958\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.5033\ \text{kipft/ft})) + (3 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]^2}{(8.25\ \text{ft})^2 \times [(3 \times (9.5033\ \text{kipft/ft})) + (2 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.28274\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.5033\ \text{kipft/ft})) + ((-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.175\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.6958\ \text{ft})}{2}$$

$$p_a = 0.42719\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.28274 \text{ kip/ft}^2)}{(0.42719 \text{ kip/ft}^2)}$$

$$Ratio = 0.66187$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.175 \text{ kip/ft}^2)}{(1.2375 \text{ kip/ft}^2)}$$

$$Ratio = 0.9495$$

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

Considering z-direction:

$H_o = -0.03328 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.13105 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.13105 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.03328 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.13105 \text{ kipft/ft})) + (4 \times (-0.03328 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.9006 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.13105 \text{ kipft/ft})) + (3 \times (-0.03328 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (0.13105 \text{ kipft/ft})) + (2 \times (-0.03328 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = -0.0063365 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.13105 \text{ kipft/ft})) + ((-0.03328 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = -0.0010984 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.9006 \text{ ft})}{2}$$

$$p_a = 0.44255 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0063365 \text{ kip/ft}^2)}{(0.44255 \text{ kip/ft}^2)}$$

$$Ratio = -0.014318$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

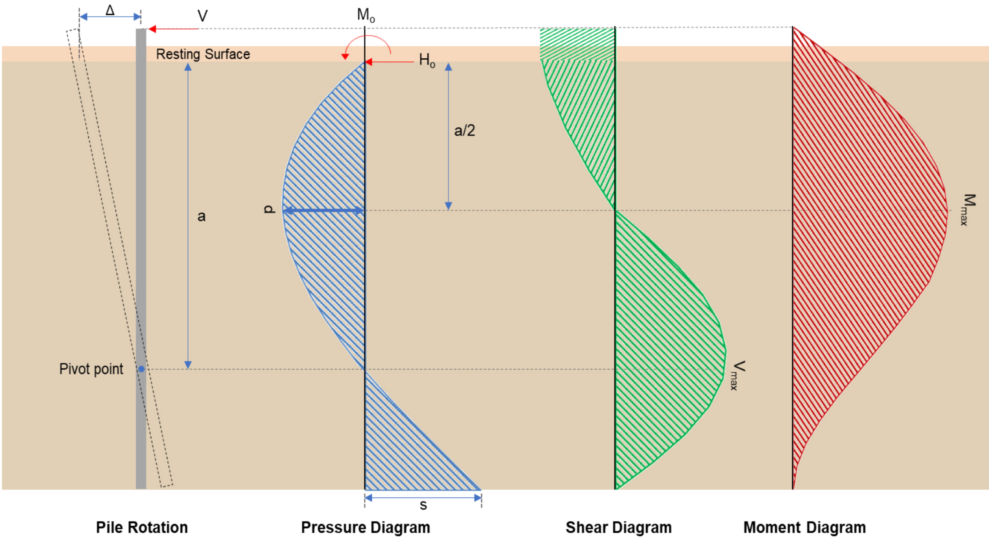
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0010984\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.00088761$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.211\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.1482\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(101.47\ \text{kipft}) + ((-7.211\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 16.158\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(16.158\ \text{kipft/ft})}{(-1.1482\ \text{kip/ft})}$$

$$E = 14.072\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.158\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-1.1482\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (16.158\ \text{kipft/ft})) + (4 \times (-1.1482\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6932\ \text{ft}$$

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

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

$$V_{max} = ((-1.1482\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.072\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6932\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.072\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6932\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.892\ \text{kip}$$

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

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

$$M_{max} = ((-1.1482\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.072\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.072\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.072\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 66.238\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.339\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.053981\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.341\ \text{kipft}) + ((-0.339\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.21354\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.21354\ \text{kipft/ft})}{(-0.053981\ \text{kip/ft})}$$

$$E = 3.9558\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.21354\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.053981\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.21354\ \text{kipft/ft})) + (4 \times (-0.053981\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9\ \text{ft}$$

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

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

$$V_{max} = ((-0.053981\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9558\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9558\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.32716\ \text{kip}$$

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

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

$$M_{max} = ((-0.053981\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(3.9558\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.9558\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9558\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.1907\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.429\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.05\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.05\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.429\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0061413$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.429 \text{ kip} \rightarrow 16429 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16429 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.68 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.68 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.68 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.68 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.52 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.892 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(16.892 \text{ kip})}{(111.52 \text{ kip})}$$

$$Ratio = 0.15147$$

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

Considering z-direction:

$V_{max} = 0.32716 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.32716 \text{ kip})}{(111.52 \text{ kip})}$$

$$Ratio = 0.0029336$$

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:

$M_{max} = 66.238 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(66.238 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.26538$$

Status: **PASS**
Ratio: **0.270**

Considering z-direction:

$M_{max} = 1.1907 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.1907\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0047705$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

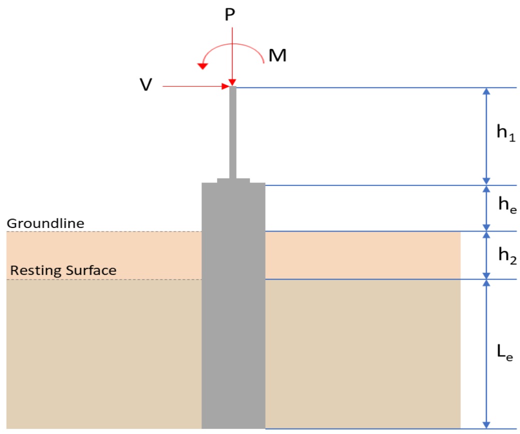
SkyCiv Foundation Design

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
$L = 8.25\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.768	15.685
V_x (kip)	-4.160	-6.952
V_z (kip)	0.033	0.054
M_x (kipft)	0.127	0.207
M_z (kipft)	57.498	97.350

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,

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

$$H_o = \frac{(-4.16\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.66242\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(57.498\text{ kipft}) + ((-4.16\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 9.1557\text{ kipft/ft}$$

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:
$L_{e,x} = 7.5595\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.033\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0052548\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.127\text{ kipft}) + ((0.033\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.020223\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.2632\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.5595\text{ ft}), (1.2632\text{ ft})]$$

$$L_{e,req} = 7.56\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.56\text{ ft})}{(8.25\text{ ft})}$$

$$Ratio = 0.91636$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.768\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.673\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.673\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.3365$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66242\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.1557\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1557\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (9.1557\ \text{kipft/ft})) + (4 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6957\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.1557\ \text{kipft/ft})) + (3 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]^{\,2}}{(8.25\ \text{ft})^2 \times [(3 \times (9.1557\ \text{kipft/ft})) + (2 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.27264\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.1557\ \text{kipft/ft})) + ((-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.1325\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.6957\ \text{ft})}{2}$$

$$p_a = 0.42718\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27264\ \mathrm{kip/ft^2}\right)}{\left(0.42718\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.63825$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1325\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91513$$

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

Considering z-direction:

$H_o = 0.0052548\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.020223\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.020223\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.020223\ \mathrm{kipft/ft})) + (4 \times (0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.9045\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.020223\ \mathrm{kipft/ft})) + (3 \times (0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\,2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.020223\ \mathrm{kipft/ft})) + (2 \times (0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.0033272\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.020223\ \mathrm{kipft/ft})) + ((0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 0.0073871\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9045\ \mathrm{ft})}{2}$$

$$p_a = 0.44284\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0033272\ \mathrm{kip/ft^2}\right)}{\left(0.44284\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0075135$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

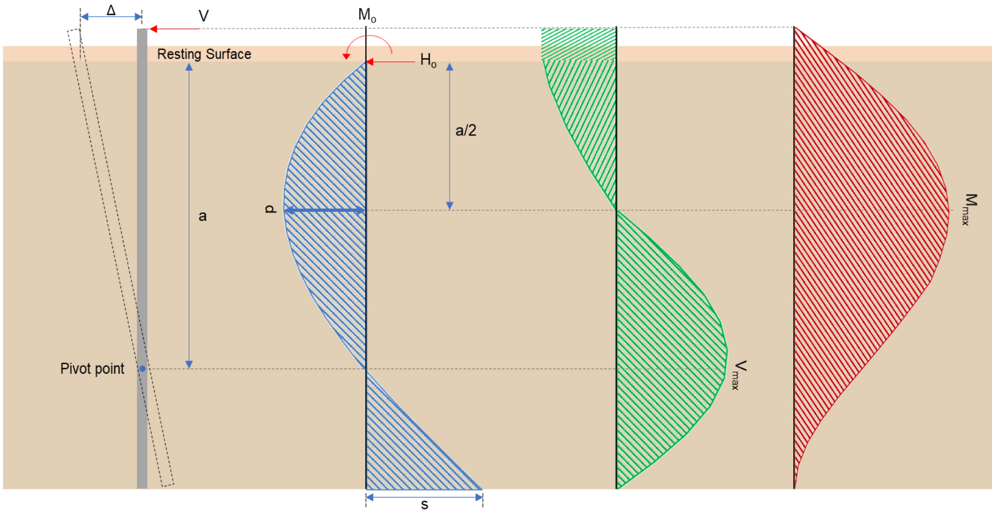
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0073871\ \mathrm{kip/ft^2})}{(1.2375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0059694$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.952\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.107\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(97.35\ \mathrm{kipft}) + ((-6.952\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.502\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.502\ \mathrm{kipft/ft})}{(-1.107\ \mathrm{kip/ft})}$$

$$E = 14.003\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.502\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.107\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{\ldots}{(6 \times (15.502\ \text{kipft/ft})) + (4 \times (-1.107\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6939\ \text{ft}$$

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

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

$$V_{max} = ((-1.107\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6939\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6939\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.22\ \text{kip}$$

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

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

$$M_{max} = ((-1.107\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.003\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 63.591\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.054\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0085987\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.207\ \text{kipft}) + ((0.054\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.032962\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.032962\ \text{kipft/ft})}{(0.0085987\ \text{kip/ft})}$$

$$E = 3.8333\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032962\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.0085987\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.032962\ \text{kipft/ft})) + (4 \times (0.0085987\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9051\ \text{ft}$$

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

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

$$V_{max} = ((0.0085987\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9051\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9051\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.051221\ \text{kip}$$

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

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

$$M_{max} = ((0.0085987\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(3.8333\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.186\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.685\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.075\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.075\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$Ratio = \frac{(15.685\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0058632$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 15.685\ \text{kip} \rightarrow 15685\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(15685\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.58\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.58\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.58\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.58\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.46\ \text{kip}$$

Considering x-direction:

$V_{max} = 16.22\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(16.22\text{ kip})}{(111.46\text{ kip})}$$ $$Ratio = 0.14553$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $V_{max} = 0.051221\text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.051221\text{ kip})}{(111.46\text{ kip})}$$ $$Ratio = 0.00045957$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\text{ in}) \times (48\text{ in})^2}{6}$$ $$S_m = 18432\text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 63.591\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(63.591\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.25477$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 0.186\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.186\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0007452$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

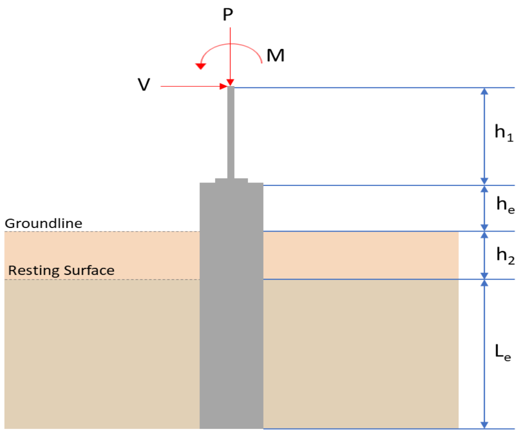
SkyCiv Foundation Design

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

$L = 8.25$ 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)	10.768	15.685
V_x (kip)	-4.160	-6.952
V_z (kip)	-0.033	-0.054
M_x (kipft)	-0.127	-0.207
M_z (kipft)	57.498	97.350

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.16\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.66242\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(57.498\ \text{kipft}) + ((-4.16\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 9.1557\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.5595\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.033\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0052548\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.127\ \text{kipft}) + ((-0.033\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.020223\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.0846\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.5595\ \text{ft}), (1.0846\ \text{ft})]$$

$$L_{e,req} = 7.56\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.56\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.91636$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.768\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.673\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.673\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.3365$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66242\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.1557\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1557\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (9.1557\ \text{kipft/ft})) + (4 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6957\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.1557\ \text{kipft/ft})) + (3 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]^{\ 2}}{(8.25\ \text{ft})^2 \times [(3 \times (9.1557\ \text{kipft/ft})) + (2 \times (-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.27264\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.1557\ \text{kipft/ft})) + ((-0.66242\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.1325\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.6957\ \text{ft})}{2}$$

$$p_a = 0.42718\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27264\ \mathrm{kip/ft^2}\right)}{\left(0.42718\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.63825$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1325\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91513$$

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

Considering z-direction:

$H_o = -0.0052548\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.020223\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.020223\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.020223\ \mathrm{kipft/ft})) + (4 \times (-0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.9045\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[(4 \times (0.020223\ \mathrm{kipft/ft})) + (3 \times (-0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))\right]^2}{(8.25\ \mathrm{ft})^2 \times \left[(3 \times (0.020223\ \mathrm{kipft/ft})) + (2 \times (-0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))\right]}$$

$$p = -0.001023\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[(2 \times (0.020223\ \mathrm{kipft/ft})) + ((-0.0052548\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))\right]}{(8.25\ \mathrm{ft})^2}$$

$$s = -0.00025618\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9045\ \mathrm{ft})}{2}$$

$$p_a = 0.44284\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.001023\ \mathrm{kip/ft^2}\right)}{\left(0.44284\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0023102$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

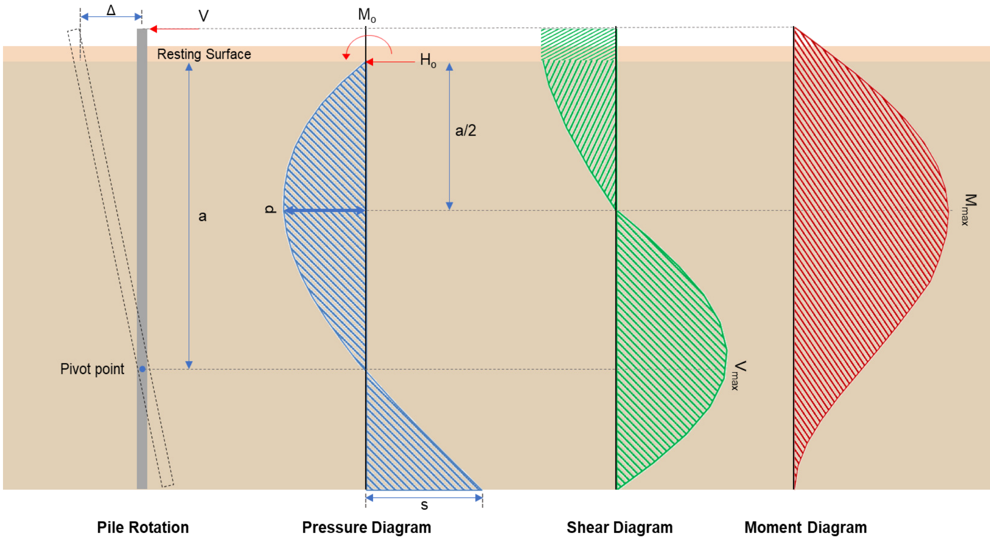
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00025618\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00020701$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.952\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.107\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(97.35\ \mathrm{kipft}) + ((-6.952\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.502\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.502\ \mathrm{kipft/ft})}{(-1.107\ \mathrm{kip/ft})}$$

$$E = 14.003\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.502\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.107\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (15.502\ \text{kipft/ft})) + (4 \times (-1.107\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6939\ \text{ft}$$

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

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

$$V_{max} = ((-1.107\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6939\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6939\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.22\ \text{kip}$$

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

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

$$M_{max} = ((-1.107\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.003\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.003\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6939\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 63.591\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.054\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0085987\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.207\ \text{kipft}) + ((-0.054\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.032962\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.032962\ \text{kipft/ft})}{(-0.0085987\ \text{kip/ft})}$$

$$E = 3.8333\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032962\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.0085987\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.032962\ \text{kipft/ft})) + (4 \times (-0.0085987\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9051\ \text{ft}$$

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

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

$$V_{max} = ((-0.0085987\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9051\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9051\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.051221\ \text{kip}$$

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

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

$$M_{max} = ((-0.0085987\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(3.8333\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8333\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.9051\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.186\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.685\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.075\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.075\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.685\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0058632$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.685 \text{ kip} \rightarrow 15685 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15685 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.58 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.58 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.58 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.58 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.46 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.22 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(16.22\ \text{kip})}{(111.46\ \text{kip})}$$ $$Ratio = 0.14553$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $V_{max} = 0.051221\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.051221\ \text{kip})}{(111.46\ \text{kip})}$$ $$Ratio = 0.00045957$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 63.591\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(63.591\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.25477$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 0.186\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.186 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0007452$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

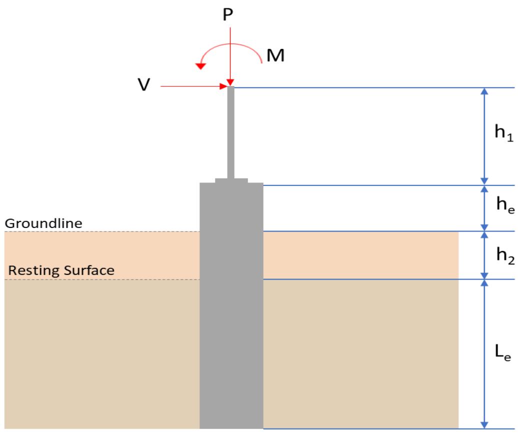
SkyCiv Foundation Design

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
$L = 8.25$ 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)	11.270	16.429
V_x (kip)	-4.322	-7.210
V_z (kip)	0.209	0.339
M_x (kipft)	0.823	1.341
M_z (kipft)	59.681	101.470

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.322\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.68822\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.681\ \text{kipft}) + ((-4.322\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 9.5033\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6347\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.209\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.03328\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.823\ \text{kipft}) + ((0.209\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.13105\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.4911\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.6347\ \text{ft}), (2.4911\ \text{ft})]$$

$$L_{e,req} = 7.635\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.635\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.92545$$

Status: **PASS**
Ratio: **0.930**

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

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

$$q = \frac{(11.27\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.70438\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.70438\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.35219$$

Status: **PASS**
Ratio: **0.350**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.68822\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.5033\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.5033\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (9.5033\ \text{kipft/ft})) + (4 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6958\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.5033\ \text{kipft/ft})) + (3 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]^{\ 2}}{(8.25\ \text{ft})^2 \times [(3 \times (9.5033\ \text{kipft/ft})) + (2 \times (-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.28274\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.5033\ \text{kipft/ft})) + ((-0.68822\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.175\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.6958\ \text{ft})}{2}$$

$$p_a = 0.42719\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.28274\ \text{kip/ft}^2\right)}{\left(0.42719\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.66187$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.175\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.9495$$

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

Considering z-direction:

$H_o = 0.03328\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.13105\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.13105\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.03328\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.13105\ \text{kipft/ft})) + (4 \times (0.03328\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9006\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.13105\ \text{kipft/ft})) + (3 \times (0.03328\ \text{kip/ft}) \times (8.25\ \text{ft}))]^{\ 2}}{(8.25\ \text{ft})^2 \times [(3 \times (0.13105\ \text{kipft/ft})) + (2 \times (0.03328\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.021246\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.13105\ \text{kipft/ft})) + ((0.03328\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 0.047309\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.9006\ \text{ft})}{2}$$

$$p_a = 0.44255\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.021246\ \text{kip/ft}^2\right)}{\left(0.44255\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.048009$$

Status: **PASS**
Ratio: **0.050**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

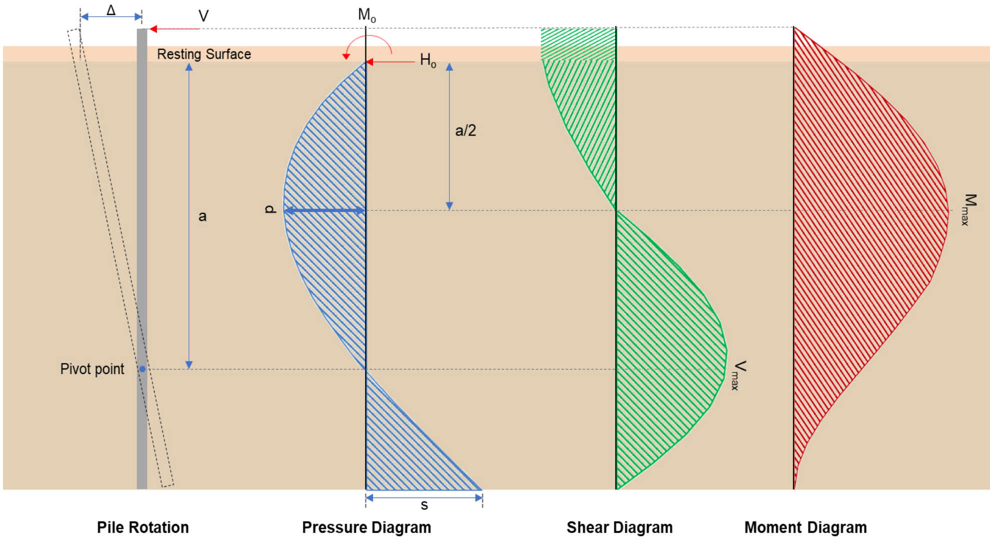
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.047309\ \mathrm{kip/ft^2})}{(1.2375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.03823$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.21\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1481\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(101.47\ \mathrm{kipft}) + ((-7.21\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 16.158\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(16.158\ \mathrm{kipft/ft})}{(-1.1481\ \mathrm{kip/ft})}$$

$$E = 14.074\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.158\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.1481\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (16.158\ \text{kipft/ft})) + (4 \times (-1.1481\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6932\ \text{ft}$$

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

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

$$V_{max} = ((-1.1481\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.074\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6932\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.074\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6932\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 16.891\ \text{kip}$$

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

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

$$M_{max} = ((-1.1481\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.074\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.074\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.074\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6932\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 66.237\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.339\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.053981\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.341\ \text{kipft}) + ((0.339\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.21354\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.21354\ \text{kipft/ft})}{(0.053981\ \text{kip/ft})}$$

$$E = 3.9558\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.21354\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.053981\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.21354\ \text{kipft/ft})) + (4 \times (0.053981\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.9\ \text{ft}$$

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

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

$$V_{max} = ((0.053981 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9558 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.9 \text{ ft})}{(8.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9558 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.9 \text{ ft})}{(8.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.32716 \text{ kip}$$

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

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

$$M_{max} = ((0.053981 \text{ kip/ft}) \times (48 \text{ in}) \times (8.25 \text{ ft})) \times \left[\left(\frac{(3.9558 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.9 \text{ ft})}{2 \times (8.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.9558 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.9 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9558 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.9 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.1907 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.429 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.05 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.05 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.429\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0061413$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.429 \text{ kip} \rightarrow 16429 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16429 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.68 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.68 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.68 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.68 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.52 \text{ kip}$$

Considering x-direction:

$V_{max} = 16.891 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(16.891\ \text{kip})}{(111.52\ \text{kip})}$$ $$Ratio = 0.15146$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $V_{max} = 0.32716\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.32716\ \text{kip})}{(111.52\ \text{kip})}$$ $$Ratio = 0.0029336$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 66.237\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(66.237\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.26537$$	Status: **PASS** Ratio: **0.270**
	Considering z-direction: $M_{max} = 1.1907\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.1907\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0047705$$	Status: **PASS** Ratio: **0.000**