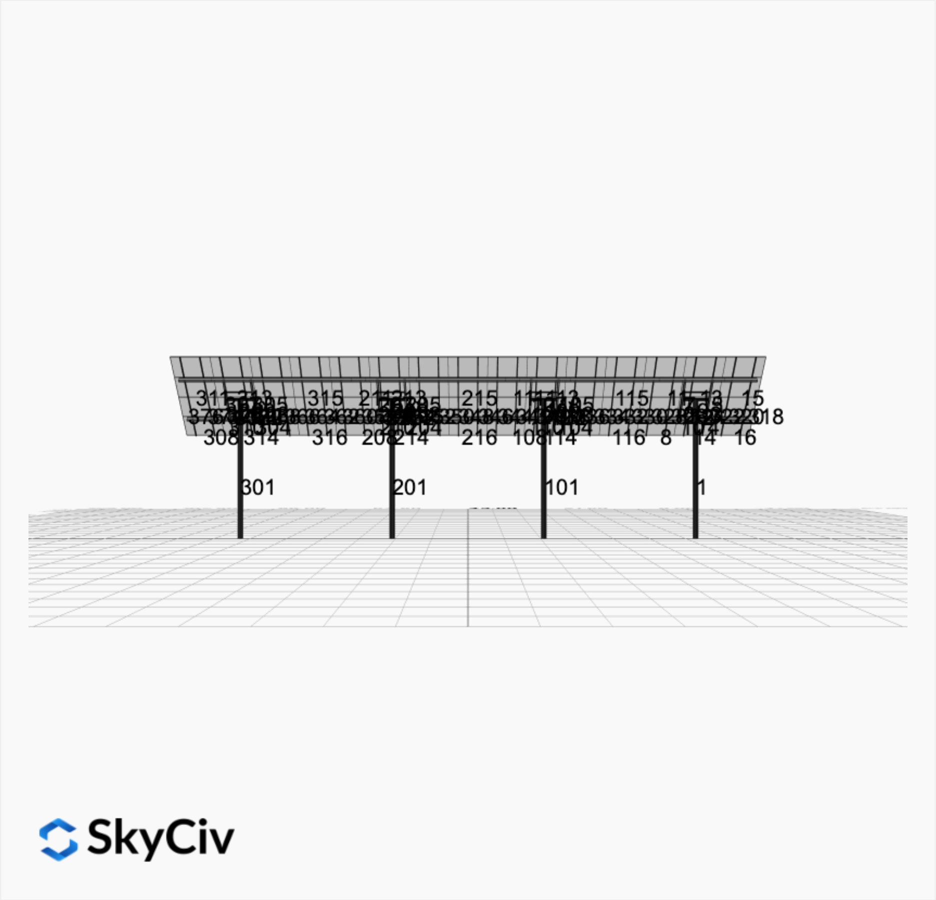
Project Details

Project Name: Bob Grunbeck - V1Jb
Location: 80 South St, Milford, NH 03055, USA
Unique ID: 4P-22.5-8TOP-HD-57-L-4Hx15W-95DC
Dealer: ______________________________

Date: Wed Dec 11 2024
Number of Modules: 60
Number of Poles: 4
Date Sold: ______________________________



Array Dimensions N/S	15.03 ft
Array Dimensions E/W	86.00 ft
Winter Tilt Angle	48
Front Edge Clearance	15 ft

MT Solar Bill of Materials (4P-22.5-8TOP-HD-57-L-4Hx15W-95DC)

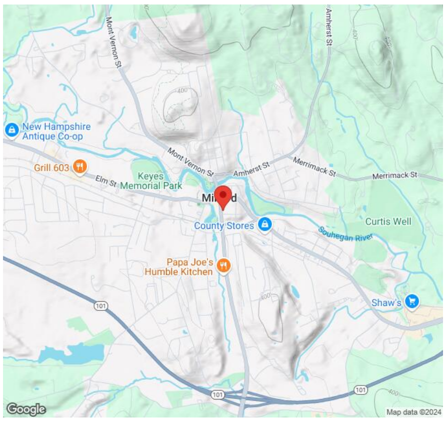
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-HD	H-Frame Assembly-HD	4
MTS-HD-Wing-57	57IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	12
MTS-CLAMP-HOOK-4PK	Hook Clamp	15

Rail Bill of Materials

Part	Qty
Rails (178in)	30
Rail Attachment	60
Module Mid Clamp	90
Module End Clamp	60

Part	Qty
Ground Lug	15

Site Details:



Site Address: 80 South St, Milford, NH 03055, USA

Array Specification

Duty Classification:	HD
Module Width:	44.60 in
Module Length:	67.80in
Number of Rows:	4
Number of Columns:	15
Total Number of Modules:	60
Winter Tilt Angle:	48
Front Edge Clearance:	15
Total Array Height at Tilt:	26.17 ft
Total Frame Length:	84.50 ft
Frame Weight:	7396 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	86.00 ft
Rail Length:	180.40 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	20.59 ft
Number of Poles:	4
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 8.25 ft Pile 2: 8.50 ft Pile 3: 8.50 ft Pile 4: 8.25 ft
Foundation Volume:	19.852 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	80 South St, Milford, NH 03055, USA
Wind Speed:	106 mph

Snow Load:	60 psf

Design Disclaimer

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

AutoDesigner Input

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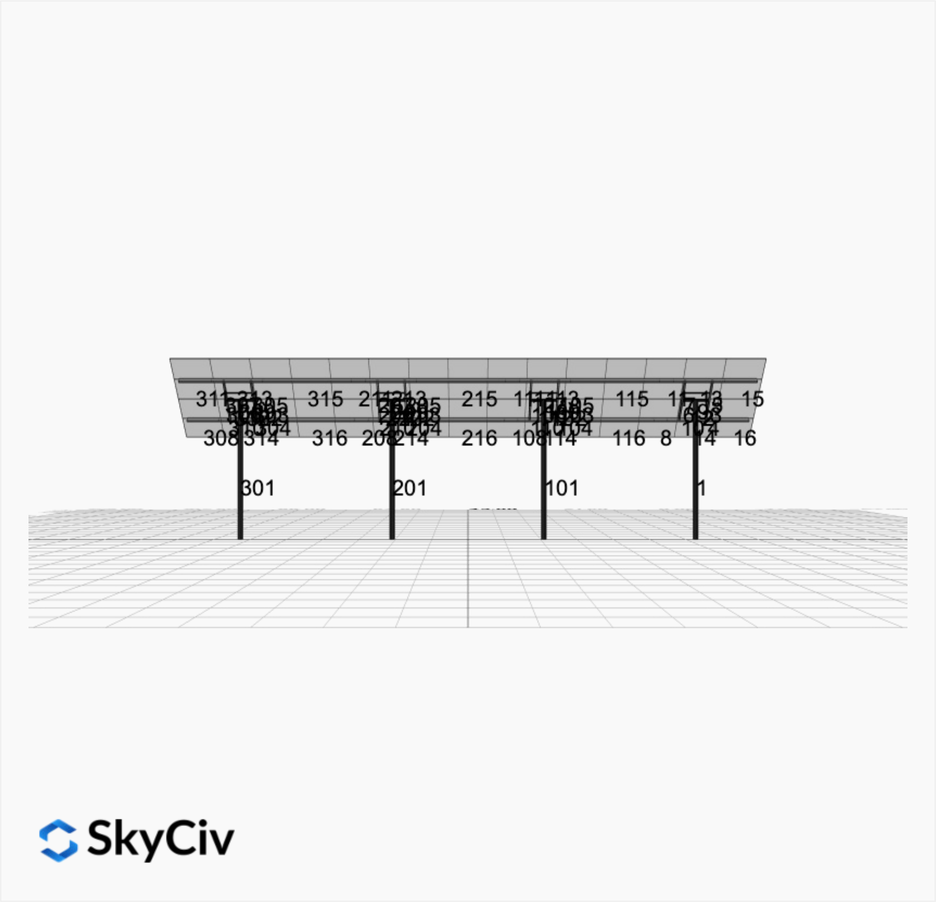
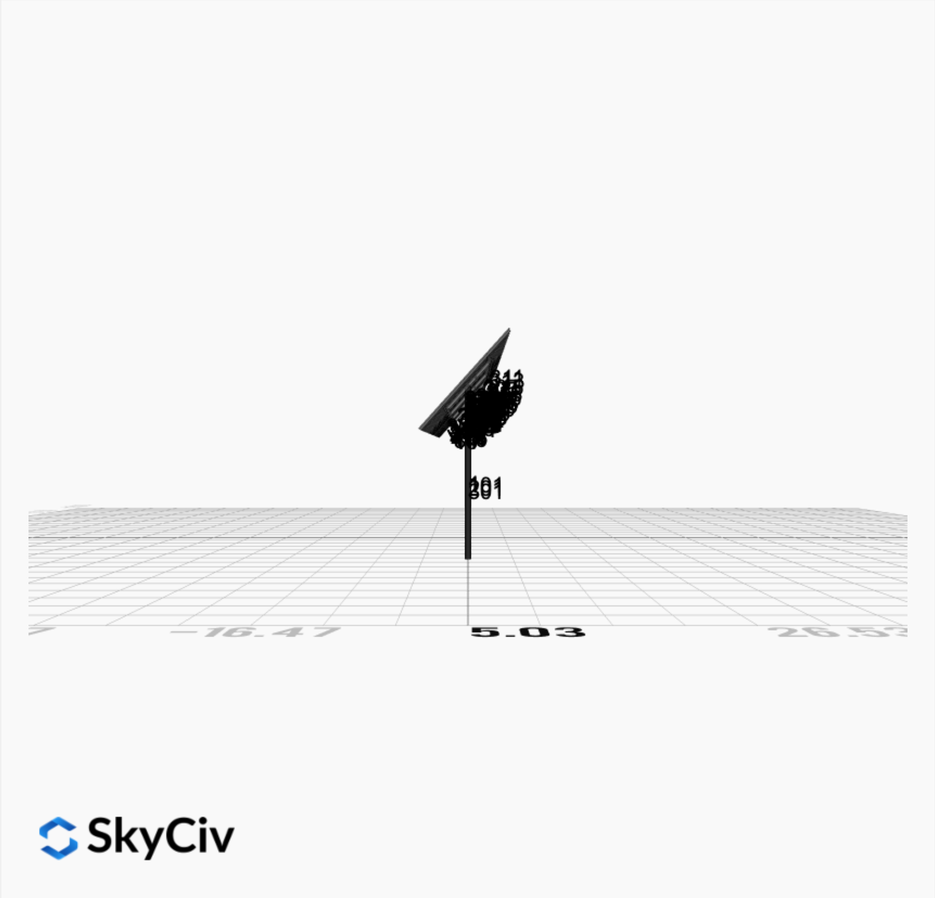
Design Notes:

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

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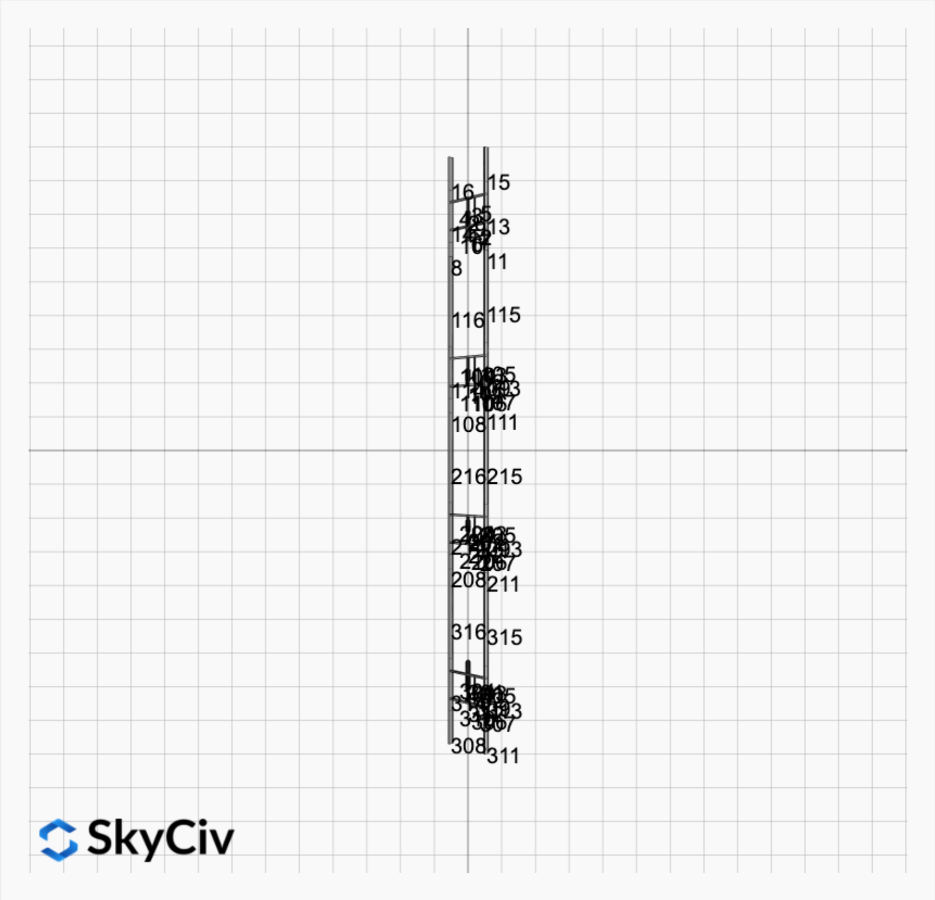
SkyCiv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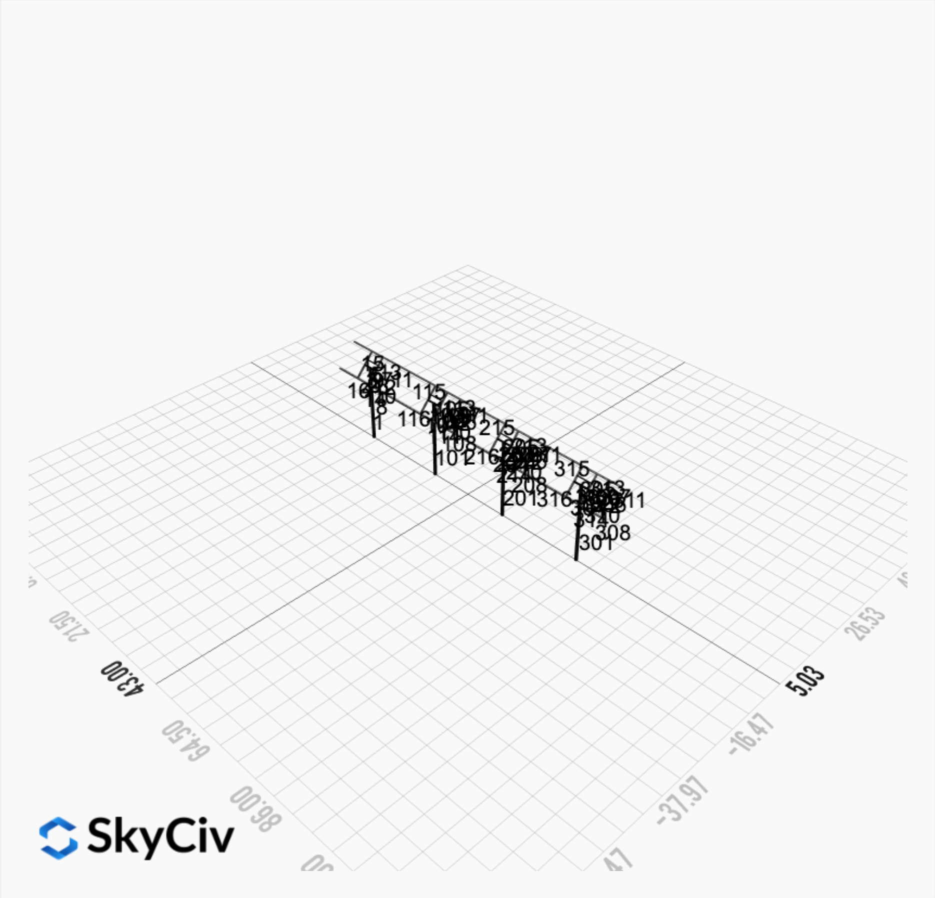
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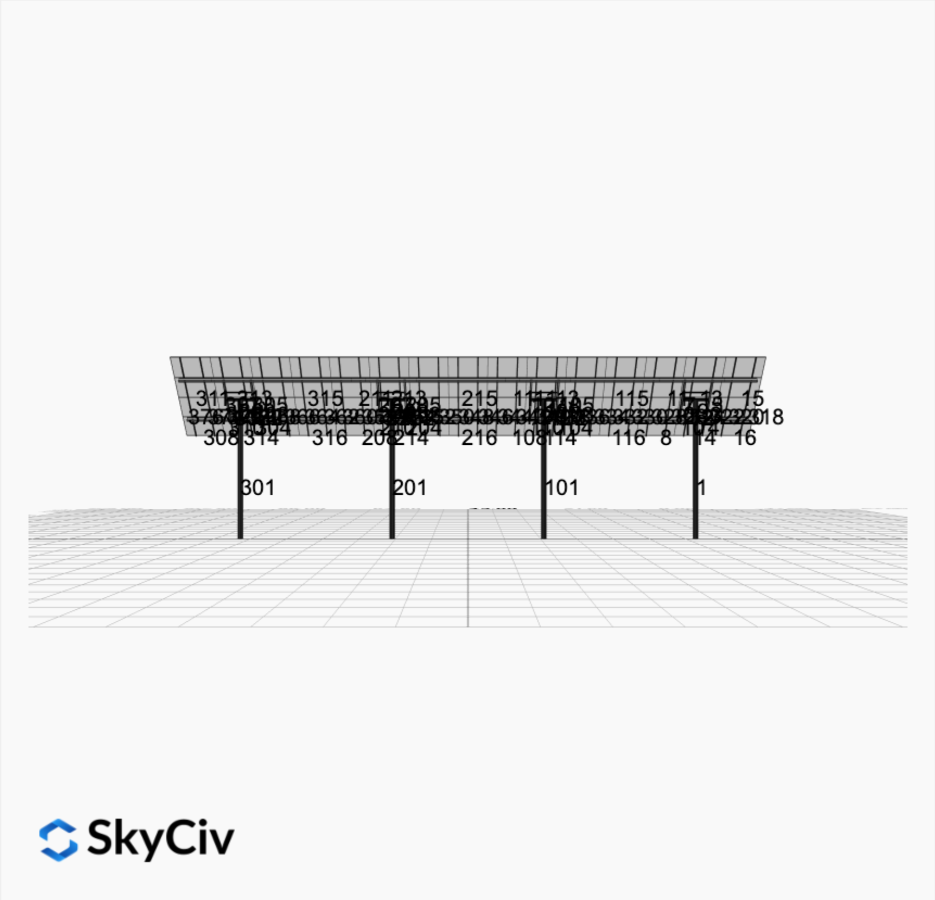
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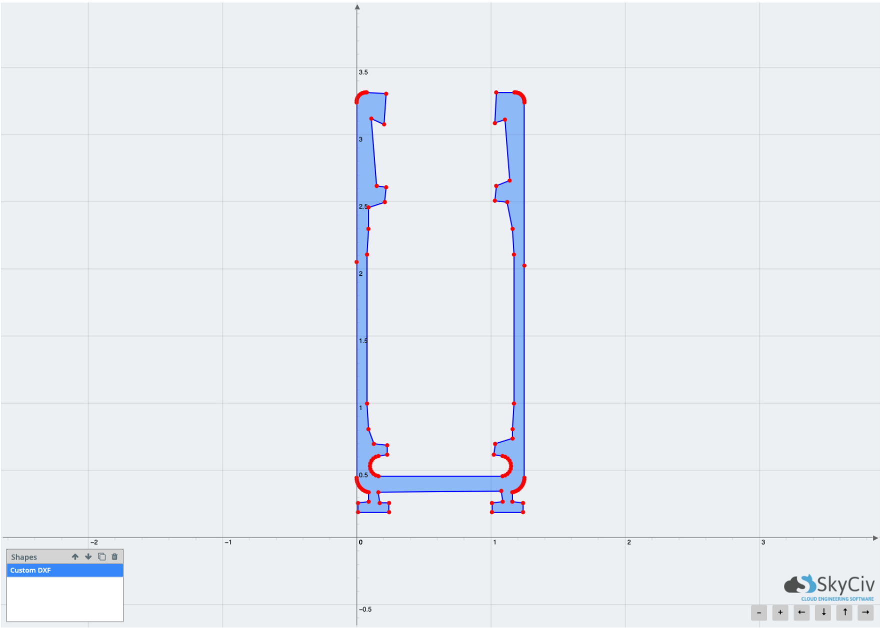
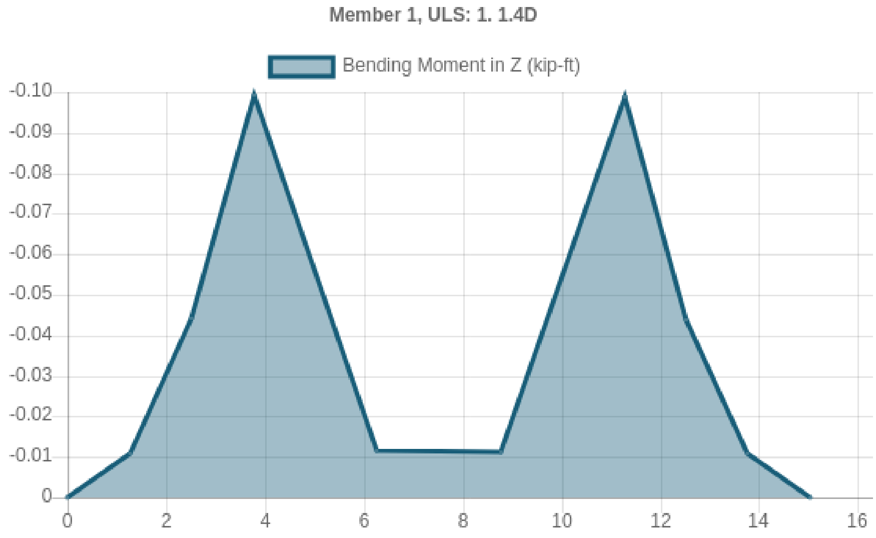
216
108
114
116
8
14
16
18
301
201
101
1
SkyCiv

Rail Design Check

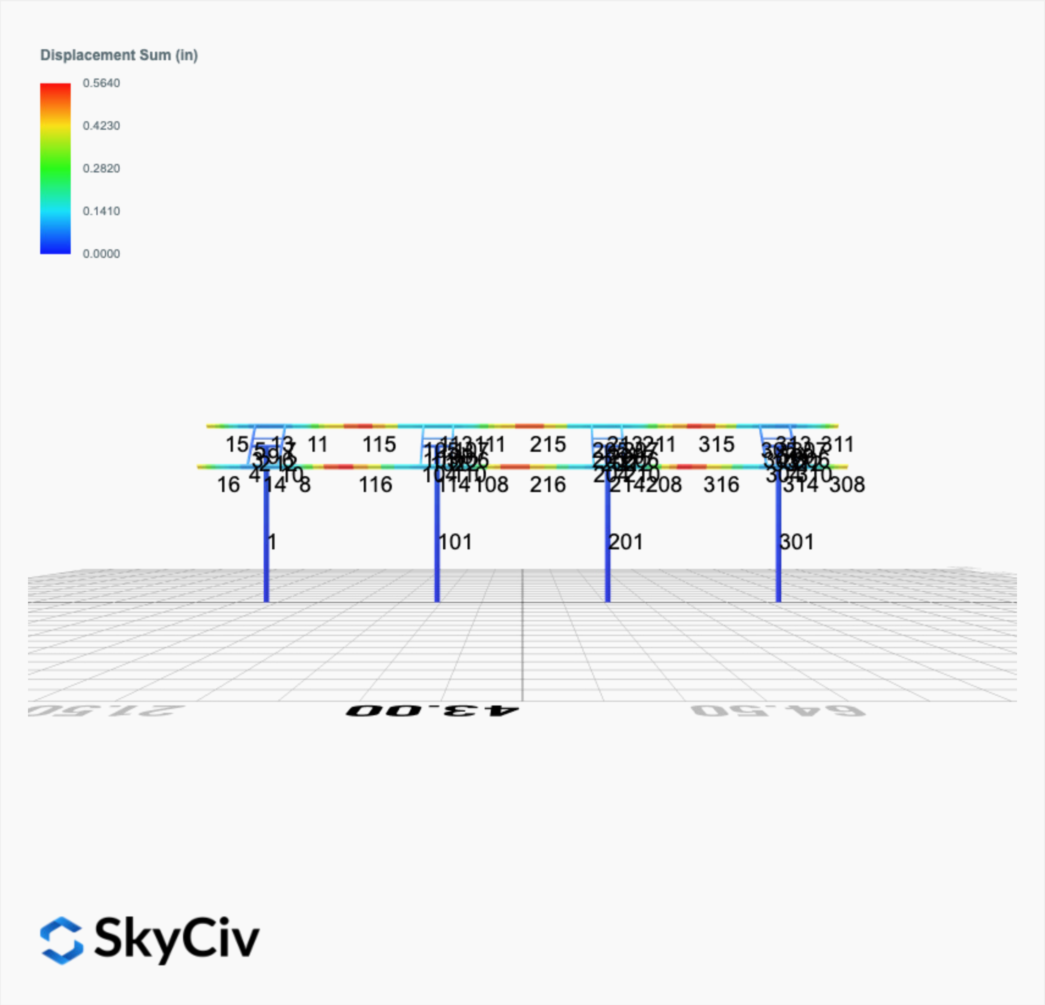
Rail Length: 15.033333333333333 ft
Additional Restraints Required: None
Tributary Width: 2.8666666666666667 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0278 kip/ft
Snow (Y): -0.0309 kip/ft
Wind uplift Case A: 0.0510 kip/ft
Wind downforce Case A: 0.0510 kip/ft
Dead (Panel load) (X): 0.0090 kip/ft
Dead (Panel load) (Y): -0.0100 kip/ft

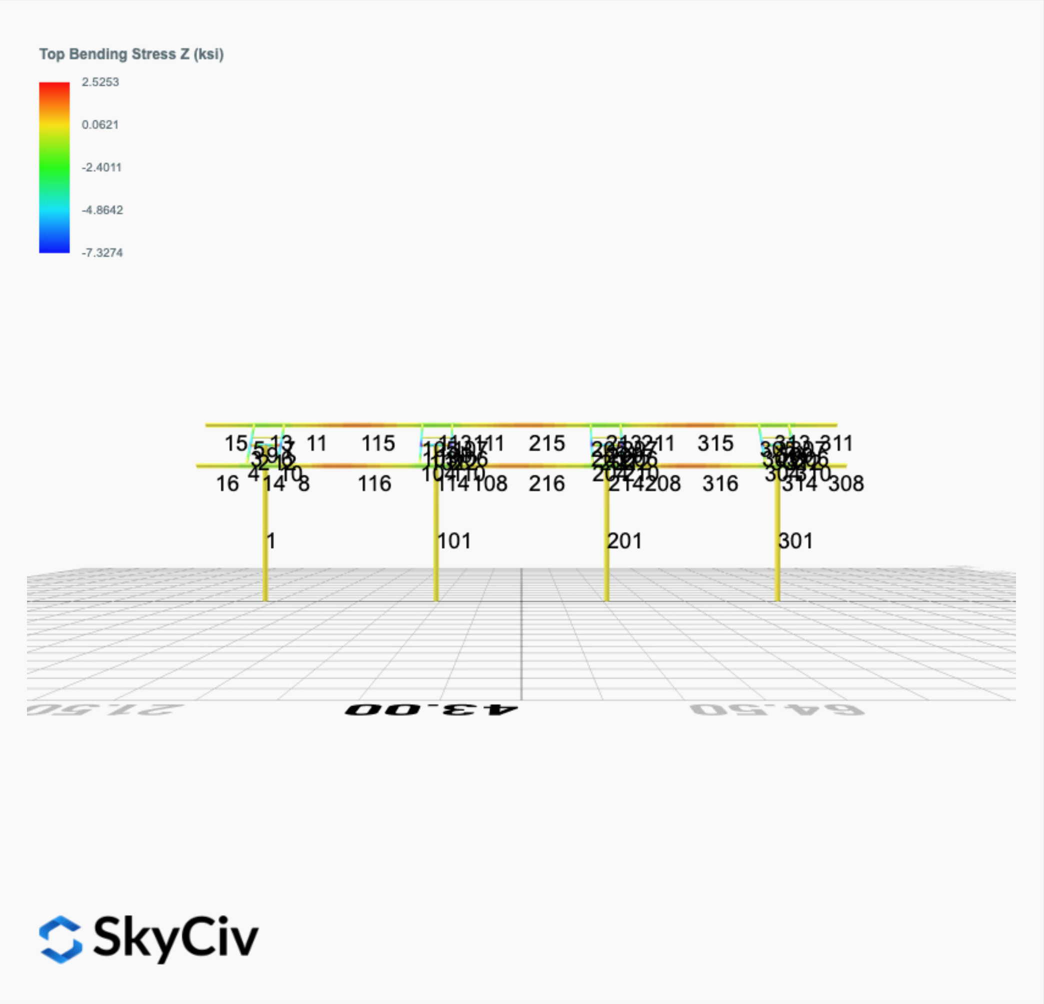


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	13.56053277	0.393	PASS
Material Yield	34.5	13.56053277	0.393	PASS
Material Strength	37	13.56053277	0.367	PASS



FEM Results (Envelope Worst Case for each member)

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-2.4011
-4.8642
-7.3274
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115
215
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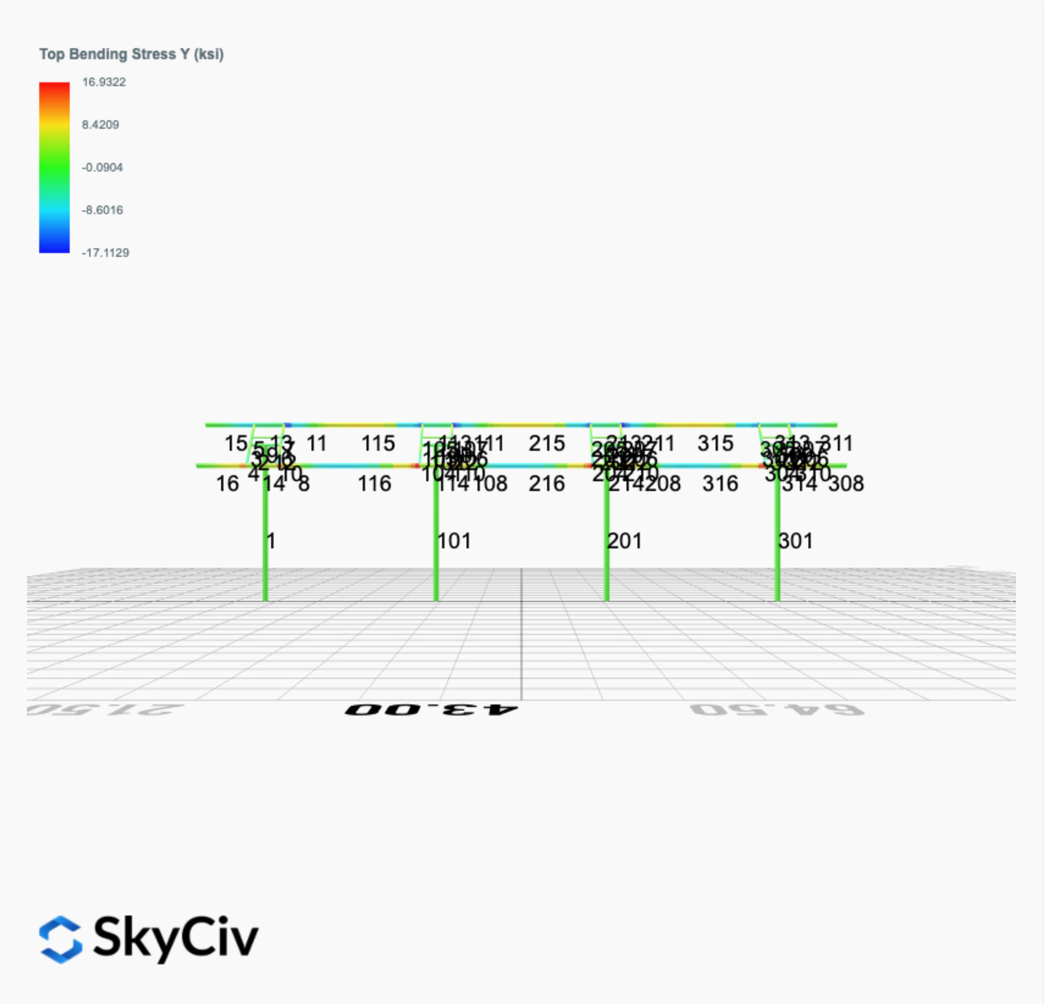
216
316
1
101
201
301
43.00
64.50
21.50
SkyCiv


Top Bending Stress Y (ksi)
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8.4209
-0.0904
-8.6016
-17.1129
15
13
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43.00
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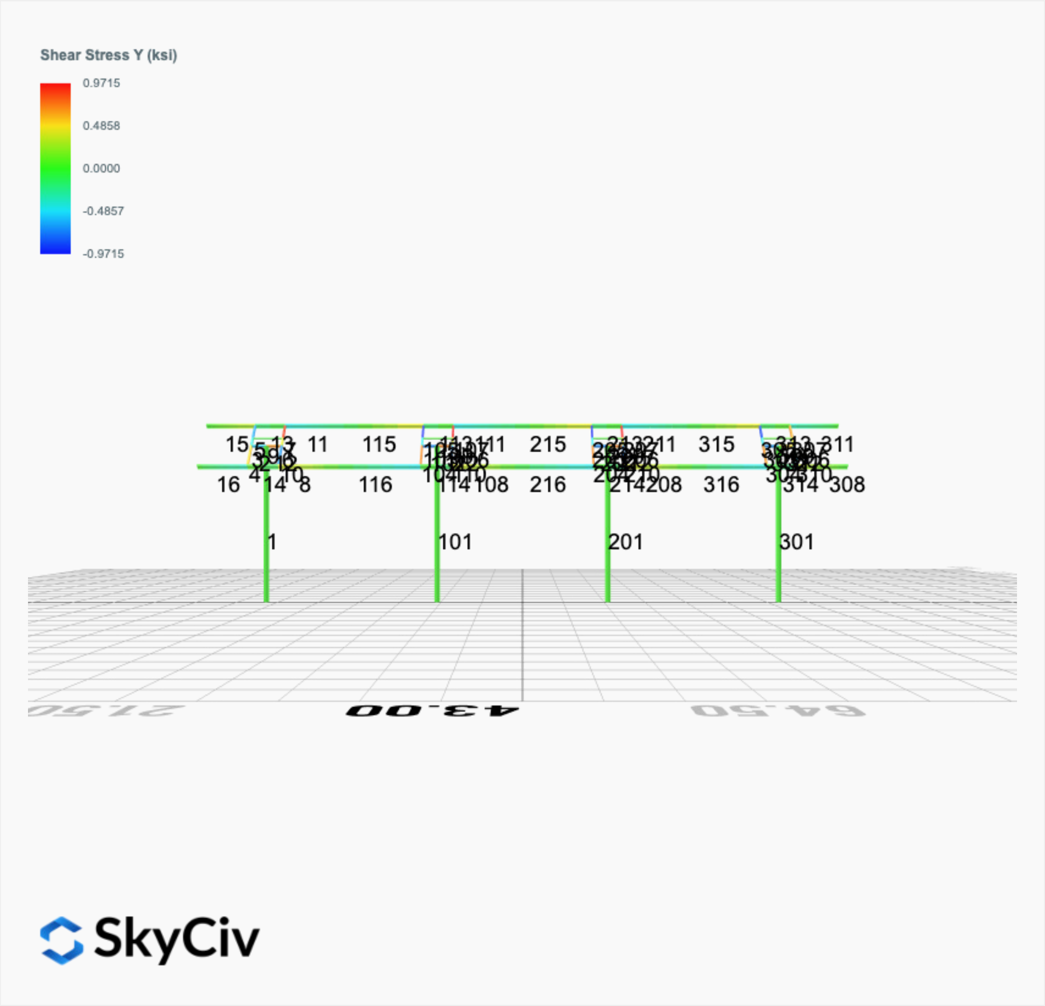
64.50
SkyCiv


Shear Stress Y (ksi)
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-0.9715
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13
11
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111
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211
315
311
16
14
8
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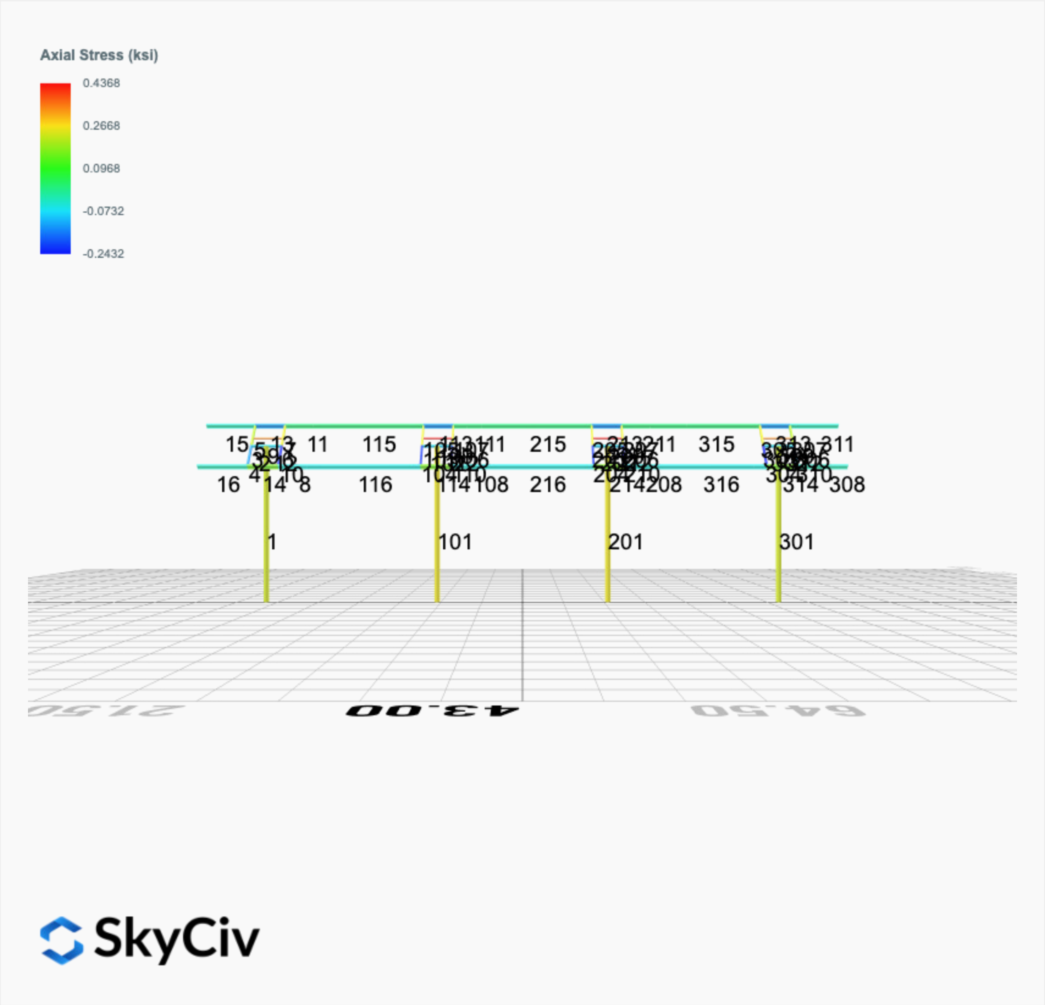
21.50
43.00
64.50
SkyCiv


Axial Stress (ksi)
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0.0968
-0.0732
-0.2432
15
13
11
115
111
215
211
315
313
311
16
4
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
21.50
43.00
64.50
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 2. D + L	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 3. D + (S or Lr or R)	0.0182	5.7851	0.0506	0.3435	-0.0771	-0.3278
ULS: 3. D + (S or Lr or R)	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0154	5.0674	0.0428	0.2907	-0.0652	-0.2750
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 5b. D + 0.7E	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0154	5.0674	0.0428	0.2907	-0.0652	-0.2750
ULS: 8. 0.6D + 0.7E	0.0042	1.7487	0.0117	0.0793	-0.0177	-0.0700
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4382	5.0768	0.0942	0.6224	-0.5737	51.5969
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4459	0.7551	-0.0510	-0.3282	0.4839	-49.2712
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8185	6.6891	0.0989	0.6584	-0.4734	38.5102
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0154	5.0674	0.0428	0.2907	-0.0652	-0.2750
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8446	3.4479	-0.0100	-0.0546	0.3198	-37.1409
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0154	5.0674	0.0428	0.2907	-0.0652	-0.2750
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8269	4.5362	0.0756	0.4998	-0.4376	38.6685
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8362	1.2949	-0.0334	-0.2131	0.3556	-36.9826
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0070	2.9145	0.0195	0.1321	-0.0294	-0.1167
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4410	3.9110	0.0864	0.5696	-0.5620	51.6436
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0042	1.7487	0.0117	0.0793	-0.0177	-0.0700
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4431	-0.4107	-0.0588	-0.3811	0.4957	-49.2245
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0042	1.7487	0.0117	0.0793	-0.0177	-0.0700

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	9.8945
Shear X	-4.0852
Shear Z	0.1682
Moment X	1.1145
Moment Y (Twist)	1.0007
Moment Z	89.2152

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.6891
Shear X	-2.4459
Shear Z	0.0989
Moment X	0.6584
Moment Y (Twist)	0.5737
Moment Z	51.6436

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	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 2. D + L	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 3. D + (S or Lr or R)	-0.0182	6.4825	-0.0006	-0.0049	-0.0122	0.3994
ULS: 3. D + (S or Lr or R)	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0154	5.6579	-0.0005	-0.0042	-0.0103	0.3401

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 5b. D + 0.7E	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0154	5.6579	-0.0005	-0.0042	-0.0103	0.3401
ULS: 8. 0.6D + 0.7E	-0.0042	1.9104	-0.0002	-0.0012	-0.0028	0.0974
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6903	5.6394	0.0263	0.1718	-0.2204	56.8117
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.6825	0.7258	-0.0241	-0.1568	0.1901	-53.6347
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0278	7.4994	0.0194	0.1261	-0.1722	42.8271
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0154	5.6579	-0.0005	-0.0042	-0.0103	0.3401
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0018	3.8142	-0.0184	-0.1203	0.1357	-40.0077
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0154	5.6579	-0.0005	-0.0042	-0.0103	0.3401
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0194	5.0255	0.0197	0.1283	-0.1665	42.6493
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0101	1.3404	-0.0181	-0.1181	0.1414	-40.1855
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0070	3.1840	-0.0003	-0.0020	-0.0046	0.1623
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6874	4.3657	0.0264	0.1726	-0.2186	56.7468
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0042	1.9104	-0.0002	-0.0012	-0.0028	0.0974
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.6853	-0.5478	-0.0240	-0.1560	0.1919	-53.6997
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0042	1.9104	-0.0002	-0.0012	-0.0028	0.0974

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.1423
Shear X	-4.4826
Shear Z	0.0471
Moment X	0.3072
Moment Y (Twist)	0.3942
Moment Z	98.3552

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.4994
Shear X	-2.6903
Shear Z	0.0264
Moment X	0.1726
Moment Y (Twist)	0.2204
Moment Z	56.8117

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	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 2. D + L	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 3. D + (S or Lr or R)	-0.0182	6.4825	0.0006	0.0039	0.0123	0.3990
ULS: 3. D + (S or Lr or R)	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0154	5.6579	0.0005	0.0033	0.0104	0.3398
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 5b. D + 0.7E	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0154	5.6579	0.0005	0.0033	0.0104	0.3398
ULS: 8. 0.6D + 0.7E	-0.0042	1.9104	0.0002	0.0010	0.0028	0.0973
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6902	5.6393	-0.0264	-0.1726	0.2196	56.8110
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.6825	0.7258	0.0241	0.1569	-0.1892	-53.6344
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0278	7.4994	-0.0194	-0.1273	0.1716	42.8264
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0154	5.6579	0.0005	0.0033	0.0104	0.3398
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0018	3.8142	0.0184	0.1198	-0.1350	-40.0077
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0154	5.6579	0.0005	0.0033	0.0104	0.3398
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0194	5.0255	-0.0197	-0.1291	0.1659	42.6488
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0101	1.3404	0.0181	0.1181	-0.1408	-40.1853
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0070	3.1840	0.0003	0.0016	0.0047	0.1622
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6874	4.3657	-0.0265	-0.1733	0.2177	56.7462
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0042	1.9104	0.0002	0.0010	0.0028	0.0973
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.6853	-0.5478	0.0240	0.1563	-0.1911	-53.6993
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0042	1.9104	0.0002	0.0010	0.0028	0.0973

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.1422
Shear X	-4.4826
Shear Z	-0.0471
Moment X	-0.3090
Moment Y (Twist)	0.3925
Moment Z	98.3545

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.4994
Shear X	-2.6902
Shear Z	-0.0265
Moment X	-0.1733
Moment Y (Twist)	0.2196
Moment Z	56.8110

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	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 2. D + L	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 3. D + (S or Lr or R)	0.0182	5.7850	-0.0506	-0.3446	0.0768	-0.3278
ULS: 3. D + (S or Lr or R)	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0154	5.0674	-0.0428	-0.2916	0.0649	-0.2751
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 5b. D + 0.7E	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0154	5.0674	-0.0428	-0.2916	0.0649	-0.2751
ULS: 8. 0.6D + 0.7E	0.0042	1.7487	-0.0117	-0.0795	0.0176	-0.0700
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4382	5.0767	-0.0942	-0.6229	0.5731	51.5962
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4459	0.7551	0.0510	0.3279	-0.4835	-49.2706
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8185	6.6891	-0.0989	-0.6594	0.4727	38.5096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0154	5.0674	-0.0428	-0.2916	0.0649	-0.2751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8445	3.4478	0.0100	0.0538	-0.3197	-37.1404
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0154	5.0674	-0.0428	-0.2916	0.0649	-0.2751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8269	4.5362	-0.0755	-0.5003	0.4371	38.6679
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8362	1.2949	0.0333	0.2128	-0.3553	-36.9821
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0070	2.9144	-0.0195	-0.1325	0.0293	-0.1167

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4410	3.9110	-0.0864	-0.5699	0.5614	51.6429
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0042	1.7487	-0.0117	-0.0795	0.0176	-0.0700
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4431	-0.4107	0.0588	0.3809	-0.4952	-49.2239
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0042	1.7487	-0.0117	-0.0795	0.0176	-0.0700

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	9.8944
Shear X	-4.0851
Shear Z	-0.1681
Moment X	-1.1157
Moment Y (Twist)	0.9993
Moment Z	89.2148

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.6891
Shear X	-2.4459
Shear Z	-0.0989
Moment X	-0.6594
Moment Y (Twist)	0.5731
Moment Z	51.6429

Project Details

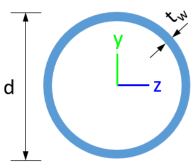
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

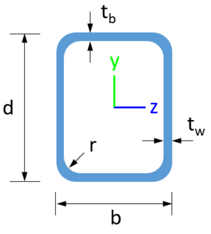
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

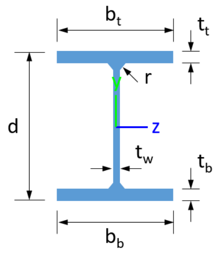
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
10	8in Pipe Sch 80	8.63	0.50					



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



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

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

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	43.23	43.23	20.59	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
4	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
7	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
8	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.11,2.09,2.13,2.09,2.11,2.09,2.12,2.09,2.10,2.09,2.07,2.09,2.11,2.09,2.14,2.09,2.11,2.09,2.12,2.09	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
11	19	1.33	1.33	2.05	2.10,2.10,2.10,2.11,2.10,2.10,2.34,2.10,2.24,2.10,2.35,2.10,2.29,2.10,2.14,2.11,1.64,2.11,2.25,2.10,2.22,2.10,2.35,2.10,2.30,2.10	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.05,1.08,1.08,1.08,1.05,1.08,1.05,1.08,1.07,1.08,1.15,1.08,1.06,1.08,1.10,1.08,1.05,1.08,1.04,1.08	300	200	1
14	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.03,1.08,1.06,1.08,1.05,1.08,1.07,1.08,1.13,1.08,1.06,1.08,1.04,1.08,1.06,1.08,1.05,1.08	300	200	1
15	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	43.23	43.23	20.59	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
105	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
107	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
108	19	1.33	1.33	2.05	2.29,2.29,2.29,2.29,2.29,2.29,2.21,2.29,2.09,2.29,2.15,2.29,2.11,2.29,2.34,2.29,1.95,2.29,2.27,2.29,2.08,2.29,2.14,2.29,2.12,2.29	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
111	19	1.33	1.33	2.05	2.31,2.31,2.31,2.31,2.31,2.31,2.10,2.31,1.63,2.31,2.09,2.31,1.85,2.31,2.14,2.31,1.64,2.31,2.11,2.31,1.53,2.31,2.09,2.31,1.94,2.31	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.11,1.04,1.06,1.04,1.08,1.04,1.05,1.04,1.04,1.04,1.06,1.04,1.14,1.04,1.06,1.04,1.08,1.04	300	200	1
114	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.08,1.03,1.05,1.03,1.06,1.03,1.04,1.03,1.04,1.03,1.05,1.03,1.09,1.03,1.05,1.03,1.06,1.03	300	200	1
115	19	12.95	12.95	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.12,1.17,1.15,1.17,1.13,1.17,1.16,1.17,1.28,1.17,1.15,1.17,1.12,1.17,1.14,1.17,1.14,1.17	300	200	1
116	19	12.95	12.95	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.21,1.17,1.16,1.17,1.14,1.17,1.16,1.17,1.15,1.17	300	200	1
201	10	43.23	43.23	20.59	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	16	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
205	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1
206	16	0.92	0.92	1.42	1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
207	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1
208	19	1.33	1.33	2.05	2.34,2.34,2.34,2.34,2.34,2.34,2.12,2.34,1.99,2.34,2.12,2.34,2.09,2.34,2.15,2.34,2.10,2.34,2.13,2.34,1.84,2.34,2.11,2.34,2.09,2.34	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
211	19	1.33	1.33	2.05	2.35,2.35,2.35,2.34,2.35,2.35,1.95,2.35,1.42,2.35,1.87,2.35,1.57,2.35,2.10,2.34,1.69,2.34,2.04,2.35,1.34,2.35,1.84,2.35,1.63,2.35	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.11,1.04,1.06,1.04,1.08,1.04,1.05,1.04,1.04,1.04,1.06,1.04,1.14,1.04,1.06,1.04,1.08,1.04	300	200	1
214	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.08,1.03,1.05,1.03,1.06,1.03,1.04,1.03,1.04,1.03,1.05,1.03,1.09,1.03,1.05,1.03,1.06,1.03	300	200	1
215	19	12.95	12.95	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.11,1.16,1.13,1.16,1.12,1.16,1.15,1.16,1.35,1.16,1.14,1.16,1.10,1.16,1.13,1.16,1.12,1.16	300	200	1
216	19	12.95	12.95	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.14,1.16,1.16,1.16,1.20,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.14,1.16	300	200	1
301	10	43.23	43.23	20.59	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
305	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1
306	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
308	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1
311	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.05,1.08,1.08,1.08,1.05,1.08,1.05,1.08,1.07,1.08,1.15,1.08,1.06,1.08,1.10,1.08,1.05,1.08,1.04,1.08	300	200	1
314	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.04,1.08,1.06,1.08,1.05,1.08,1.07,1.08,1.13,1.08,1.07,1.08,1.04,1.08,1.06,1.08,1.05,1.08	300	200	1

315	19	12.95	12.95	12.95	1.15,1.15,1.15,1.15,1.15,1.15,1.17,1.15,1.20,1.15,1.17,1.15,1.19,1.15,1.16,1.15,1.15,1.15,1.17,1.15,1.21,1.15,1.18,1.15,1.18,1.15	300	200	1
316	19	12.95	12.95	12.95	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.16,1.15	300	200	1

Member Design Capacity

Member ID	Φ_tP_n (kip)	Φ_cP_n (kip)	Φ_bM_{zn} (k-ft)	Φ_bM_{yn} (k-ft)	Φ_vV_{yn} (kip)	Φ_vV_{zn} (kip)
1	574.32	88.74	123.94	123.94	172.30	172.30
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	23.84	6.12	40.24	43.62
14	133.20	85.85	23.72	6.12	40.24	43.62
15	133.20	32.95	32.87	6.12	40.24	43.62
16	133.20	32.95	32.87	6.12	40.24	43.62
101	574.32	88.74	123.94	123.94	172.30	172.30
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.74	6.12	40.24	43.62
114	133.20	85.85	23.70	6.12	40.24	43.62
115	133.20	19.55	12.09	6.12	40.24	43.62
116	133.20	19.55	12.38	6.12	40.24	43.62
201	574.32	88.74	123.94	123.94	172.30	172.30
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50

212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.74	6.12	40.24	43.62
214	133.20	85.85	23.70	6.12	40.24	43.62
215	133.20	19.55	11.97	6.12	40.24	43.62
216	133.20	19.55	12.22	6.12	40.24	43.62
301	574.32	88.74	123.94	123.94	172.30	172.30
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	32.95	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	32.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	23.84	6.12	40.24	43.62
314	133.20	85.85	23.74	6.12	40.24	43.62
315	133.20	19.55	12.46	6.12	40.24	43.62
316	133.20	19.55	12.35	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.111	0.720	0.019	0.024	0.001	0.777	#13	0.901	Not Required	Pass
2	0.005	0.262	0.169	0.065	0.031	0.392	#13	0.035	Not Required	Pass
3	0.010	0.425	0.055	0.041	0.007	0.454	#13	0.045	Not Required	Pass
4	0.009	0.426	0.192	0.042	0.040	0.529	#21	0.080	Not Required	Pass
5	0.009	0.264	0.193	0.042	0.049	0.302	#21	0.074	Not Required	Pass
6	0.013	0.539	0.078	0.054	0.010	0.583	#13	0.045	Not Required	Pass
7	0.013	0.335	0.263	0.053	0.067	0.367	#21	0.074	Not Required	Pass
8	0.003	0.047	0.277	0.037	0.022	0.284	#23	0.095	Not Required	Pass
9	0.022	0.046	0.065	0.003	0.002	0.109	#13	0.204	Not Required	Pass
10	0.013	0.517	0.254	0.051	0.053	0.618	#21	0.080	Not Required	Pass
11	0.003	0.044	0.285	0.038	0.022	0.290	#21	0.095	Not Required	Pass
12	0.005	0.350	0.214	0.083	0.040	0.544	#13	0.035	Not Required	Pass
13	0.009	0.195	0.595	0.047	0.027	0.717	#21	0.286	Not Required	Pass
14	0.011	0.188	0.585	0.045	0.027	0.693	#21	0.190	Not Required	Pass
15	0.000	0.068	0.236	0.023	0.014	0.299	#21	Not Required	Not Required	Pass
16	0.000	0.068	0.236	0.023	0.014	0.299	#21	Not Required	Not Required	Pass
101	0.126	0.794	0.005	0.026	0.000	0.850	#13	0.901	Not Required	Pass
102	0.006	0.340	0.202	0.084	0.036	0.499	#13	0.035	Not Required	Pass
103	0.013	0.516	0.065	0.051	0.002	0.563	#21	0.045	Not Required	Pass
104	0.013	0.529	0.256	0.052	0.053	0.664	#21	0.080	Not Required	Pass
105	0.013	0.320	0.266	0.051	0.068	0.377	#21	0.074	Not Required	Pass
106	0.013	0.555	0.066	0.055	0.004	0.588	#13	0.045	Not Required	Pass
107	0.013	0.344	0.256	0.054	0.066	0.390	#21	0.074	Not Required	Pass
108	0.004	0.042	0.267	0.037	0.022	0.309	#21	0.095	Not Required	Pass
109	0.026	0.042	0.050	0.002	0.000	0.097	#13	0.204	Not Required	Pass
110	0.013	0.552	0.244	0.055	0.051	0.664	#21	0.080	Not Required	Pass

111	0.003	0.050	0.273	0.037	0.022	0.309	#21	0.095	Not Required	Pass
112	0.006	0.355	0.220	0.085	0.040	0.547	#13	0.035	Not Required	Pass
113	0.010	0.170	0.604	0.045	0.027	0.753	#21	0.286	Not Required	Pass
114	0.013	0.194	0.597	0.046	0.027	0.763	#21	0.286	Not Required	Pass
115	0.020	0.364	0.318	0.035	0.022	0.649	#21	0.925	Not Required	Pass
116	0.009	0.352	0.315	0.037	0.022	0.635	#21	0.925	Not Required	Pass
201	0.126	0.794	0.005	0.026	0.000	0.850	#13	0.901	Not Required	Pass
202	0.006	0.355	0.220	0.085	0.040	0.547	#13	0.035	Not Required	Pass
203	0.013	0.555	0.066	0.055	0.004	0.588	#13	0.045	Not Required	Pass
204	0.013	0.552	0.244	0.055	0.051	0.664	#21	0.080	Not Required	Pass
205	0.013	0.345	0.256	0.054	0.066	0.390	#21	0.074	Not Required	Pass
206	0.013	0.516	0.065	0.051	0.002	0.563	#21	0.045	Not Required	Pass
207	0.013	0.320	0.266	0.051	0.068	0.377	#21	0.074	Not Required	Pass
208	0.003	0.045	0.286	0.037	0.022	0.324	#21	0.095	Not Required	Pass
209	0.026	0.042	0.050	0.002	0.000	0.097	#13	0.204	Not Required	Pass
210	0.013	0.529	0.256	0.052	0.053	0.664	#21	0.080	Not Required	Pass
211	0.003	0.058	0.292	0.035	0.022	0.321	#21	0.095	Not Required	Pass
212	0.006	0.340	0.202	0.084	0.036	0.499	#13	0.035	Not Required	Pass
213	0.010	0.170	0.604	0.045	0.027	0.753	#21	0.286	Not Required	Pass
214	0.013	0.194	0.597	0.046	0.027	0.763	#21	0.286	Not Required	Pass
215	0.022	0.366	0.310	0.037	0.022	0.630	#21	0.925	Not Required	Pass
216	0.015	0.332	0.310	0.037	0.022	0.606	#21	0.925	Not Required	Pass
301	0.111	0.720	0.019	0.024	0.001	0.777	#13	0.901	Not Required	Pass
302	0.005	0.350	0.214	0.083	0.040	0.544	#13	0.035	Not Required	Pass
303	0.013	0.539	0.078	0.054	0.010	0.583	#13	0.045	Not Required	Pass
304	0.013	0.517	0.254	0.051	0.053	0.618	#21	0.080	Not Required	Pass
305	0.013	0.335	0.263	0.053	0.067	0.368	#21	0.074	Not Required	Pass
306	0.010	0.425	0.055	0.041	0.007	0.454	#13	0.045	Not Required	Pass
307	0.009	0.264	0.193	0.042	0.049	0.302	#21	0.074	Not Required	Pass
308	0.000	0.068	0.236	0.023	0.014	0.299	#21	Not Required	Not Required	Pass
309	0.022	0.046	0.065	0.003	0.002	0.109	#13	0.204	Not Required	Pass
310	0.009	0.426	0.192	0.042	0.040	0.529	#21	0.080	Not Required	Pass
311	0.000	0.068	0.236	0.023	0.014	0.299	#21	Not Required	Not Required	Pass
312	0.005	0.262	0.169	0.065	0.031	0.392	#13	0.035	Not Required	Pass
313	0.009	0.195	0.594	0.047	0.027	0.717	#21	0.190	Not Required	Pass
314	0.011	0.188	0.585	0.045	0.027	0.693	#21	0.286	Not Required	Pass
315	0.020	0.357	0.318	0.038	0.022	0.648	#21	0.925	Not Required	Pass
316	0.009	0.354	0.315	0.037	0.022	0.639	#21	0.925	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

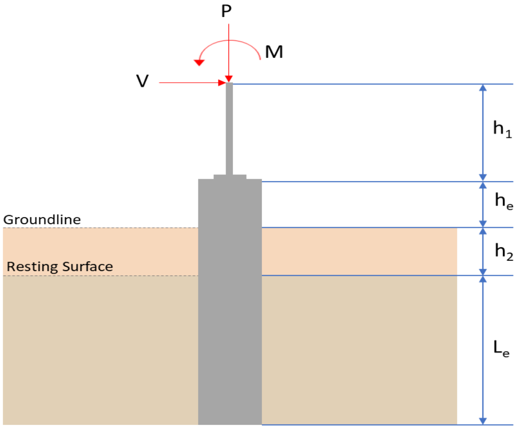
SkyCiv Foundation Design

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)	6.689	9.895
V_x (kip)	-2.446	-4.085
V_z (kip)	0.099	0.168
M_x (kipft)	0.658	1.115
M_z (kipft)	51.644	89.215

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.446\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.38949\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(51.644\ \mathrm{kipft}) + ((-2.446\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.2236\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.8051\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.099\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.015764\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.658\ \mathrm{kipft}) + ((0.099\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.10478\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.1863\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.8051\ \mathrm{ft}), (2.1863\ \mathrm{ft})]$$

$$L_{e,req} = 7.805\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.805\ \mathrm{ft})}{(8.25\ \mathrm{ft})}$$

$$Ratio = 0.94606$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.689\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.41806\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.41806\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.20903$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.38949\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.2236\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.2236\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.38949\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (8.2236\ \mathrm{kipft/ft})) + (4 \times (-0.38949\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6421\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.2236\ \mathrm{kipft/ft})) + (3 \times (-0.38949\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (8.2236\ \mathrm{kipft/ft})) + (2 \times (-0.38949\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.32662\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.2236\ \mathrm{kipft/ft})) + ((-0.38949\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1666\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6421\ \mathrm{ft})}{2}$$

$$p_a = 0.42316\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.32662\ \mathrm{kip/ft^2}\right)}{\left(0.42316\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.77186$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1666\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94272$$

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

Considering z-direction:

$H_o = 0.015764\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10478\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10478\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.015764\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.10478\ \mathrm{kipft/ft})) + (4 \times (0.015764\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.8113\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.10478\ \mathrm{kipft/ft})) + (3 \times (0.015764\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.10478\ \mathrm{kipft/ft})) + (2 \times (0.015764\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.012563\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.10478\ \mathrm{kipft/ft})) + ((0.015764\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})]}{(8.25\ \mathrm{ft})^2}$$

$$s = 0.029938\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8113\ \mathrm{ft})}{2}$$

$$p_a = 0.43585\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.012563\ \mathrm{kip/ft^2}\right)}{\left(0.43585\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.028825$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

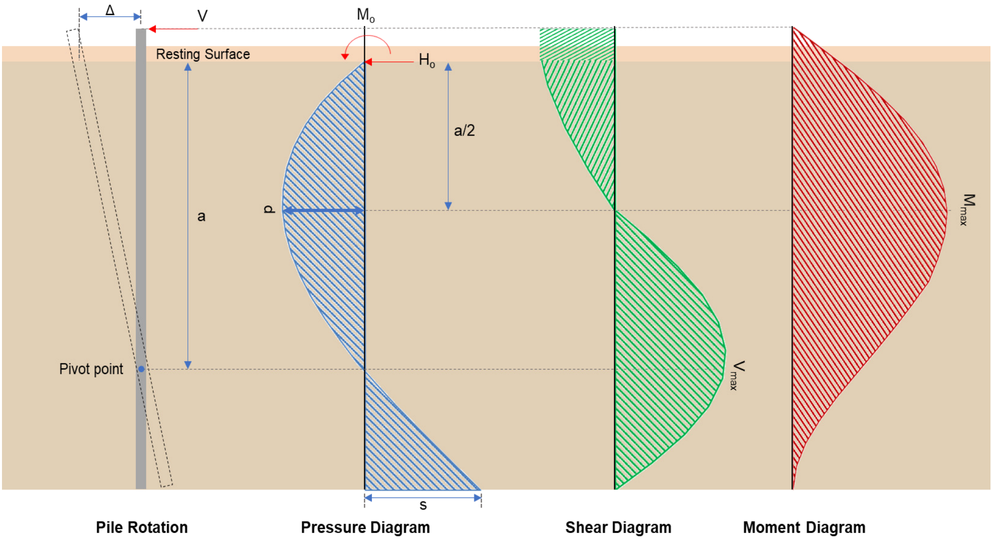
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.029938\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.024192$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.085\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.65048\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(89.215\ \text{kipft}) + ((-4.085\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 14.206\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.206\ \text{kipft/ft})}{(-0.65048\ \text{kip/ft})}$$

$$E = 21.84\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$\left(4 \times (14.206\ \text{kipft/ft}) \times (8.25\ \text{ft})\right) + \left(3 \times (-0.65048\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)$$

$$a = \frac{}{(6 \times (14.206\ \mathrm{kipft/ft})) + (4 \times (-0.65048\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6383\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.65048\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.84\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.6383\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.84\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.6383\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.913\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.65048\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.25\ \mathrm{ft})) \times \left[\left(\frac{(21.84\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + \frac{(5.6383\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.84\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.6383\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.84\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.6383\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 55.431\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.168\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.026752\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.115\ \mathrm{kipft}) + ((0.168\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.17755\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17755\ \mathrm{kipft/ft})}{(0.026752\ \mathrm{kip/ft})}$$

$$E = 6.6369\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17755\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.026752\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.17755\ \mathrm{kipft/ft})) + (4 \times (0.026752\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.8115\ \mathrm{ft}$$

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

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

$$V_{max} = \left((0.026752\ \text{kip/ft}) \times (48\ \text{in})\right) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.6369\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8115\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.6369\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8115\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.22316\ \text{kip}$$

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

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

$$M_{max} = \left((0.026752\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})\right) \times \left[\left(\frac{(6.6369\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.8115\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (6.6369\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8115\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.6369\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8115\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.84124\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.895\ \text{kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times (2304\ \text{in}^2)\right)\right]$$

$$A_{st,required} = -84.267\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.267\ \text{in}^2), \left(0.0018 \times (2304\ \text{in}^2)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

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. 10⌀: 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

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

$$Ratio = \frac{(9.895\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0036988$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.895 \text{ kip} \rightarrow 9895 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(9895 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.8 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.8 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.8 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.8 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.95 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.913 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.913\ \mathrm{kip})}{(110.95\ \mathrm{kip})}$$

$$Ratio = 0.12539$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$V_{max} = 0.22316\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.22316\ \mathrm{kip})}{(110.95\ \mathrm{kip})}$$

$$Ratio = 0.0020113$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 55.431\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(55.431\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.22208$$

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

Considering z-direction:

$M_{max} = 0.84124\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$Ratio = \frac{(0.84124 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.0033704$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

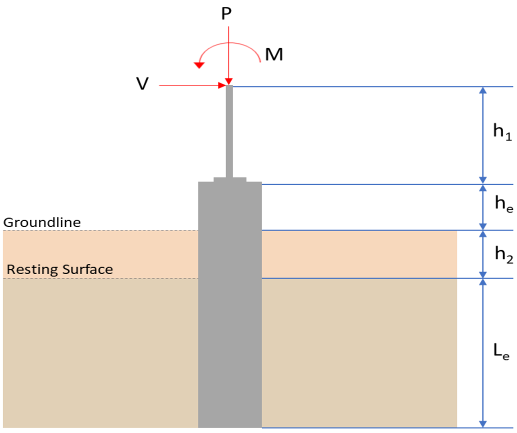
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.689	9.894
V_x (kip)	-2.446	-4.085
V_z (kip)	-0.099	-0.168
M_x (kipft)	-0.659	-1.116
M_z (kipft)	51.643	89.215

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.446\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.38949\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(51.643\ \text{kipft}) + ((-2.446\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.2234\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.805\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.099\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.015764\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.659\ \text{kipft}) + ((-0.099\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.10494\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.8776\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.805\ \text{ft}), (1.8776\ \text{ft})]$$

$$L_{e,req} = 7.805\ \text{ft}$$

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

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

$$Ratio = \frac{(7.805\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.94606$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.689\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.41806\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.41806\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.20903$$

Status: **PASS**
Ratio: **0.210**

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:

$H_o = -0.38949\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.2234\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.2234\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.38949\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (8.2234\ \text{kipft/ft})) + (4 \times (-0.38949\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6421\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.2234\ \text{kipft/ft})) + (3 \times (-0.38949\ \text{kip/ft}) \times (8.25\ \text{ft}))]^2}{(8.25\ \text{ft})^2 \times [(3 \times (8.2234\ \text{kipft/ft})) + (2 \times (-0.38949\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.32661\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.2234\ \text{kipft/ft})) + ((-0.38949\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.1666\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.6421\ \text{ft})}{2}$$

$$p_a = 0.42316\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.32661\ \mathrm{kip/ft^2}\right)}{\left(0.42316\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.77184$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1666\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9427$$

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

Considering z-direction:

$H_o = -0.015764\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10494\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(0.10494\ \mathrm{kipft/ft}\right) \times \left(8.25\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.015764\ \mathrm{kip/ft}\right) \times \left(8.25\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(0.10494\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.015764\ \mathrm{kip/ft}\right) \times \left(8.25\ \mathrm{ft}\right)\right)}$$

$$a = 5.811\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(0.10494\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.015764\ \mathrm{kip/ft}\right) \times \left(8.25\ \mathrm{ft}\right)\right)\right]^2}{\left(8.25\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(0.10494\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.015764\ \mathrm{kip/ft}\right) \times \left(8.25\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.00017625\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(0.10494\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.015764\ \mathrm{kip/ft}\right) \times \left(8.25\ \mathrm{ft}\right)\right)\right]}{\left(8.25\ \mathrm{ft}\right)^2}$$

$$s = 0.0070362\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(5.811\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.43583\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00017625\ \mathrm{kip/ft^2}\right)}{\left(0.43583\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0004044$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

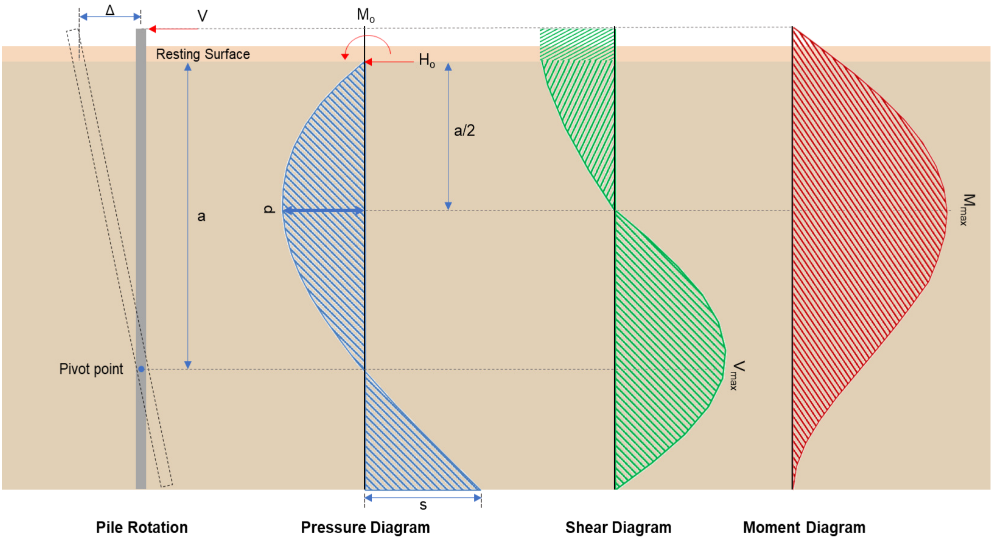
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0070362\ \text{kip/ft}^2\right)}{\left(1.2375\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.0056858$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.085\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.65048\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(89.215\ \text{kipft}) + ((-4.085\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 14.206\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.206\ \text{kipft/ft})}{(-0.65048\ \text{kip/ft})}$$

$$E = 21.84\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$(4 \times (14.206\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.65048\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)$$

$$a = \frac{\qquad}{(6 \times (14.206\ \text{kipft/ft})) + (4 \times (-0.65048\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6383\ \text{ft}$$

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

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

$$V_{max} = ((-0.65048\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.84\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6383\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.84\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6383\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.913\ \text{kip}$$

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

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

$$M_{max} = ((-0.65048\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(21.84\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6383\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (21.84\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6383\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.84\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6383\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 55.431\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.168\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.026752\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.116\ \text{kipft}) + ((-0.168\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.17771\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17771\ \text{kipft/ft})}{(-0.026752\ \text{kip/ft})}$$

$$E = 6.6429\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17771\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.026752\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.17771\ \text{kipft/ft})) + (4 \times (-0.026752\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.8114\ \text{ft}$$

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

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

$$V_{max} = ((-0.026752\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.6429\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8114\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.6429\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8114\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.22329\ \text{kip}$$

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

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

$$M_{max} = ((-0.026752\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(6.6429\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.8114\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (6.6429\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8114\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.6429\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8114\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.8418\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.894\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.267\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.267\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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,

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

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

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

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,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(9.894\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0036984$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 9.894\ \mathrm{kip} \rightarrow 9894\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(9894\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.8\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.8\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.8\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.8\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 110.95\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 13.913\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.913\ \text{kip})}{(110.95\ \text{kip})}$$

$$Ratio = 0.12539$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$V_{max} = 0.22329\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.22329\ \text{kip})}{(110.95\ \text{kip})}$$

$$Ratio = 0.0020125$$

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:

$M_{max} = 55.431\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(55.431\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.22208$$

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

Considering z-direction:

$M_{max} = 0.8418\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$Ratio = \frac{(0.8418\ \text{kipft})}{(249.6\ \text{kipft})}$ $Ratio = 0.0033726$	Status: **PASS** Ratio: **0.000**

REFERENCES | **CALCULATIONS** | **RESULTS**

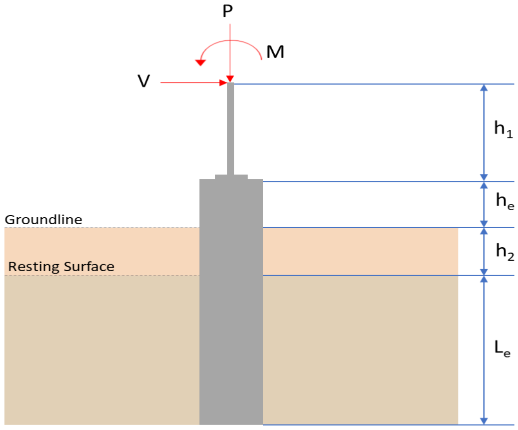
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \mathrm{in}$ - Pile width

$D = 48\ \mathrm{in}$ - Pile depth

$L = 8.5\ \mathrm{ft}$ - Total pile length

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

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

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.499	11.142
V_x (kip)	-2.690	-4.483
V_z (kip)	0.026	0.047
M_x (kipft)	0.173	0.307
M_z (kipft)	56.812	98.355

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.69\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.42834\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.812\ \mathrm{kipft}) + ((-2.69\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 9.0465\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.028\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.026\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0041401\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.173\ \mathrm{kipft}) + ((0.026\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.027548\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.365\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.028\ \mathrm{ft}), (1.365\ \mathrm{ft})]$$

$$L_{e,req} = 8.028\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.028\ \mathrm{ft})}{(8.5\ \mathrm{ft})}$$

$$Ratio = 0.94447$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.499\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.46869\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46869\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23434$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.42834\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.0465\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.0465\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (9.0465\ \mathrm{kipft/ft})) + (4 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8165\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.0465\ \mathrm{kipft/ft})) + (3 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (9.0465\ \mathrm{kipft/ft})) + (2 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.33364\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.0465\ \mathrm{kipft/ft})) + ((-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.2002\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8165\ \mathrm{ft})}{2}$$

$$p_a = 0.43624\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.33364\ \mathrm{kip/ft^2}\right)}{\left(0.43624\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.7648$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2002\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94131$$

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

Considering z-direction:

$H_o = 0.0041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.027548\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.027548\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.027548\ \mathrm{kipft/ft})) + (4 \times (0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.9925\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.027548\ \mathrm{kipft/ft})) + (3 \times (0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.027548\ \mathrm{kipft/ft})) + (2 \times (0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.003158\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.027548\ \mathrm{kipft/ft})) + ((0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0074979\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9925\ \mathrm{ft})}{2}$$

$$p_a = 0.44943\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.003158\ \mathrm{kip/ft^2}\right)}{\left(0.44943\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0070267$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

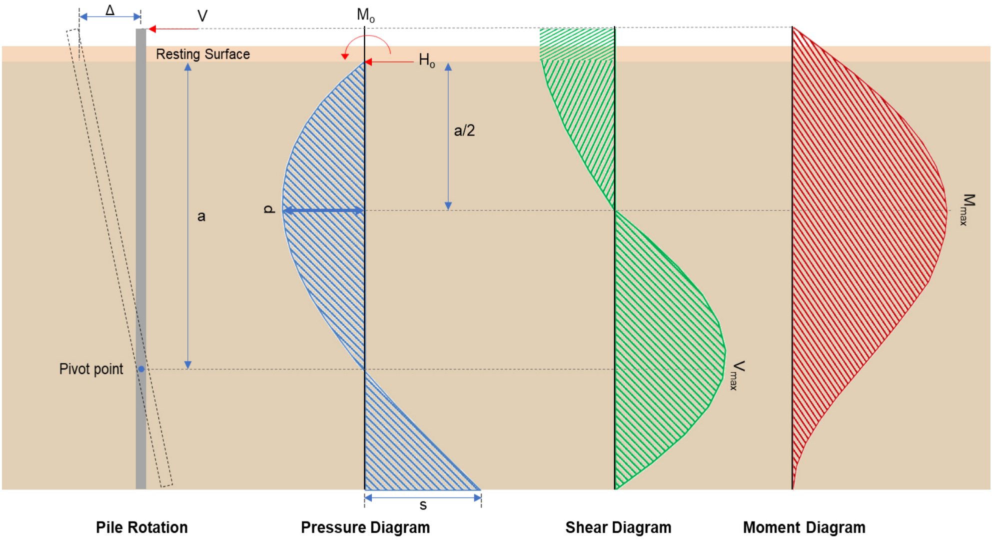
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0074979\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0058807$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.483\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.71385\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(98.355\ \mathrm{kipft}) + ((-4.483\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.662\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.662\ \mathrm{kipft/ft})}{(-0.71385\ \mathrm{kip/ft})}$$

$$E = 21.94\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$(4 \times (15.662\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.71385\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)$$

$$a = \frac{\quad}{(6 \times (15.662\ \mathrm{kipft/ft})) + (4 \times (-0.71385\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8121\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.71385\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.94\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.94\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.933\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.71385\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.5\ \mathrm{ft})) \times \left[\left(\frac{(21.94\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + \frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.94\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.94\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.252\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.047\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0074841\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.307\ \mathrm{kipft}) + ((0.047\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.048885\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.048885\ \mathrm{kipft/ft})}{(0.0074841\ \mathrm{kip/ft})}$$

$$E = 6.5319\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.048885\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0074841\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.048885\ \mathrm{kipft/ft})) + (4 \times (0.0074841\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.9957\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0074841\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.5319\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.9957\ \text{ft})}{(8.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.5319\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.9957\ \text{ft})}{(8.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.060534\ \text{kip}$$

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

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

$$M_{max} = ((0.0074841\ \text{kip/ft}) \times (48\ \text{in}) \times (8.5\ \text{ft})) \times \left[\left(\frac{(6.5319\ \text{ft})}{(8.5\ \text{ft})} + \frac{(5.9957\ \text{ft})}{2 \times (8.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (6.5319\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.9957\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.5319\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.9957\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.23443\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.142\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.226\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.226\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

$$Ratio = \frac{(11.142\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0041649$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.142 \text{ kip} \rightarrow 11142 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11142 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.97 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.97 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.97 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.06 \text{ kip}$$

Considering x-direction:

$V_{max} = 14.933 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.933\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.13446$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$V_{max} = 0.060534\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.060534\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.00054505$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 61.252\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(61.252\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.2454$$

Status: **PASS**
Ratio: **0.250**

Considering z-direction:

$M_{max} = 0.23443\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$Ratio = \frac{(0.23443 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.00093923$	Status: **PASS** Ratio: **0.000**

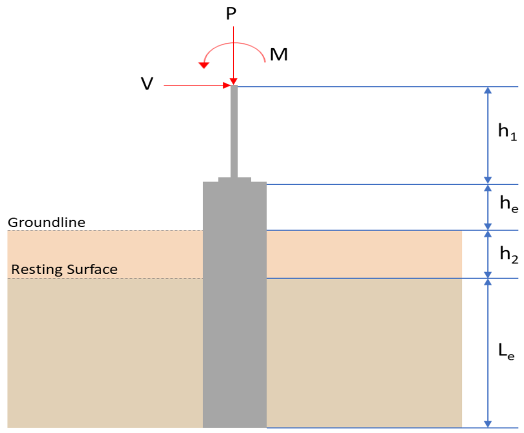
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 8.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.499	11.142
V_x (kip)	-2.690	-4.483
V_z (kip)	-0.026	-0.047
M_x (kipft)	-0.173	-0.309
M_z (kipft)	56.811	98.354

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.69\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.42834\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.811\text{ kipft}) + ((-2.69\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 9.0463\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.028\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.026\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.0041401\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.173\text{ kipft}) + ((-0.026\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.027548\text{ kipft/ft}$$

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:
$L_{e,z} = 1.2378\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.028\text{ ft}), (1.2378\text{ ft})]$$

$$L_{e,req} = 8.028\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 8.5\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.028\text{ ft})}{(8.5\text{ ft})}$$

$$Ratio = 0.94447$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.499\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.46869\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46869\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23434$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.42834\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.0463\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.0463\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (9.0463\ \mathrm{kipft/ft})) + (4 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8165\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.0463\ \mathrm{kipft/ft})) + (3 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (9.0463\ \mathrm{kipft/ft})) + (2 \times (-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.33363\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (9.0463\ \mathrm{kipft/ft})) + ((-0.42834\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.2001\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8165\ \mathrm{ft})}{2}$$

$$p_a = 0.43624\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.33363\ \mathrm{kip/ft^2}\right)}{\left(0.43624\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.76478$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2001\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94129$$

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

Considering z-direction:

$H_o = -0.0041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.027548\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.027548\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.027548\ \mathrm{kipft/ft})) + (4 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.9925\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.027548\ \mathrm{kipft/ft})) + (3 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\,2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.027548\ \mathrm{kipft/ft})) + (2 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.000018054\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.027548\ \mathrm{kipft/ft})) + ((-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.001653\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.9925\ \mathrm{ft})}{2}$$

$$p_a = 0.44943\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000018054\ \mathrm{kip/ft^2}\right)}{\left(0.44943\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00004017$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

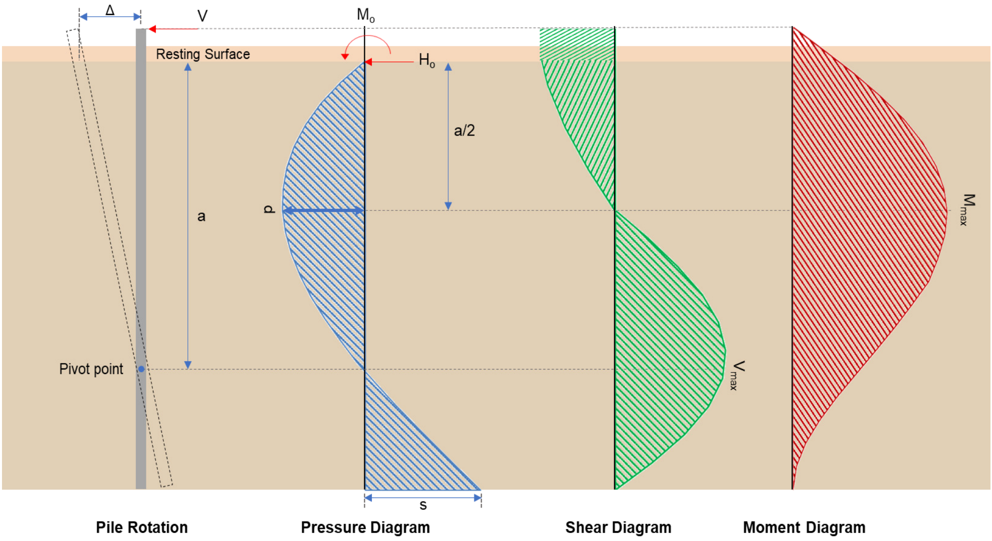
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.001653\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0012964$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.483\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.71385\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(98.354\ \mathrm{kipft}) + ((-4.483\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.661\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.661\ \mathrm{kipft/ft})}{(-0.71385\ \mathrm{kip/ft})}$$

$$E = 21.939\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$(4 \times (15.661\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.71385\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (15.661\ \mathrm{kipft/ft})) + (4 \times (-0.71385\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8121\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.71385\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (21.939\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (21.939\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.933\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.71385\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.5\ \mathrm{ft})) \times \left[\left(\frac{(21.939\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + \frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (21.939\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (21.939\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8121\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.251\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.047\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0074841\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.309\ \mathrm{kipft}) + ((-0.047\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.049204\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.049204\ \mathrm{kipft/ft})}{(-0.0074841\ \mathrm{kip/ft})}$$

$$E = 6.5745\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.049204\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0074841\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.049204\ \mathrm{kipft/ft})) + (4 \times (-0.0074841\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.9946\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0074841\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.5745\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.9946\ \text{ft})}{(8.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.5745\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.9946\ \text{ft})}{(8.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.060798\ \text{kip}$$

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

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

$$M_{max} = ((-0.0074841\ \text{kip/ft}) \times (48\ \text{in}) \times (8.5\ \text{ft})) \times \left[\left(\frac{(6.5745\ \text{ft})}{(8.5\ \text{ft})} + \frac{(5.9946\ \text{ft})}{2 \times (8.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (6.5745\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.9946\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.5745\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.9946\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.23555\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.142\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.226\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.226\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(11.142\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0041649$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.142\ \text{kip} \rightarrow 11142\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11142\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.97\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.97\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.97\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.06\ \text{kip}$$

Considering x-direction:

$V_{max} = 14.933\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.933\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.13446$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$V_{max} = 0.060798\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.060798\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.00054742$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 61.251\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(61.251\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.2454$$

Status: **PASS**
Ratio: **0.250**

Considering z-direction:

$M_{max} = 0.23555\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$Ratio = \frac{(0.23555 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.00094372$	Status: **PASS** Ratio: **0.000**