Your Project Calculations

Project Name: MTSOLAR_8D2CK4GA5141

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_8D2CK4GA5141&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=OnqODlI6ukYV3aN5KL4qFLUMIU13jCDtVCJuBLpqmlVYSyaUejNlahjUJZ6O1SZb

Array Specification

Product:	Beam
Unique ID:	4P-19.75-10TOP-XD-72-L-5Hx12W-245A
Duty Classification:	XD
Module Width:	39.50 in
Module Length:	79.10in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Desired Tilt Angle:	30
Front Edge Clearance:	14
Total Array Height at Tilt:	22.28 ft
Total Frame Length:	78.75 ft
Frame Weight:	5924 lbs
Array Dimensions N/S:	16.67 ft
Array Dimensions E/W:	80.10 ft
Rail Length:	200.00 in
Rail Spacing:	3.30 ft
Rail Check:	Not Checked

Support Specifications

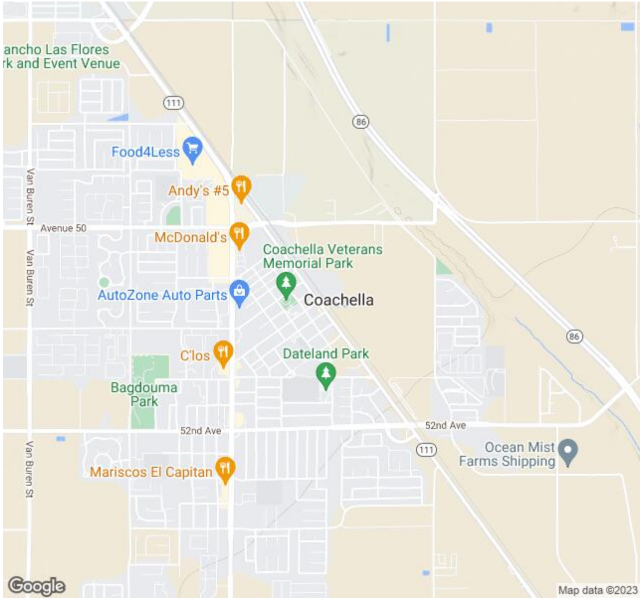
Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	18.17 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 9.25 ft Pile 2: 9.00 ft Pile 3: 9.00 ft Pile 4: 9.25 ft
Foundation Volume:	21.630 y^3
Foundation Result:	PASSED
Mount Twist:	0.995632 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	PW2R+JH, Coachella, CA, USA
Wind Speed:	110 mph
Snow Load:	0 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.000000 ksf



Design Disclaimer

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

AutoDesigner Input

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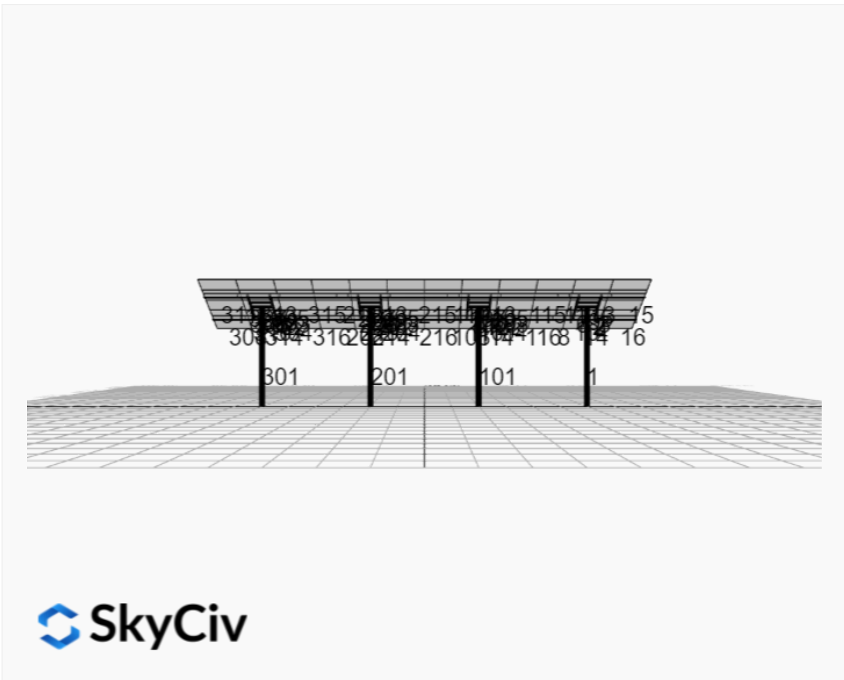
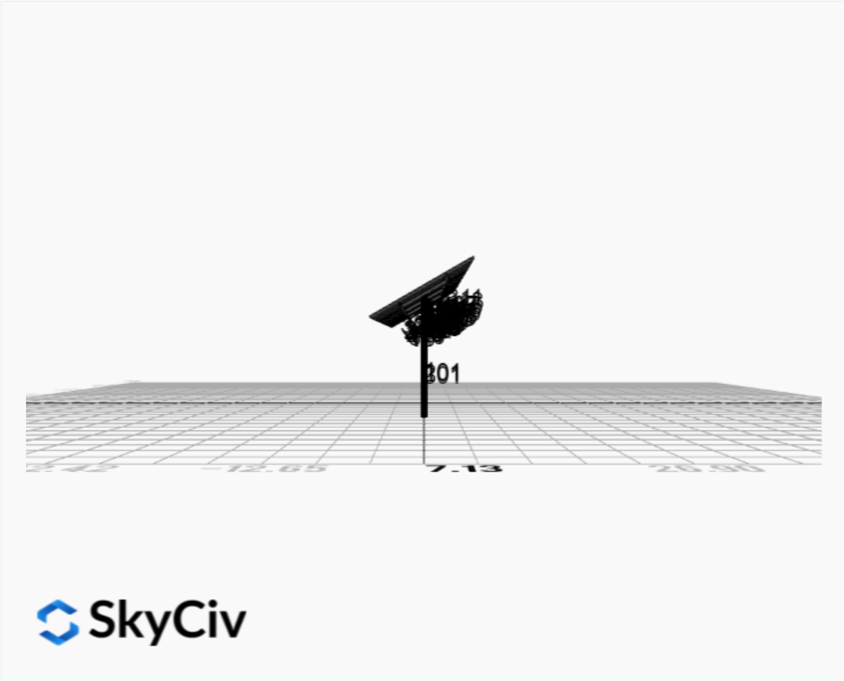
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Foundation Design and Sizing is approximate only

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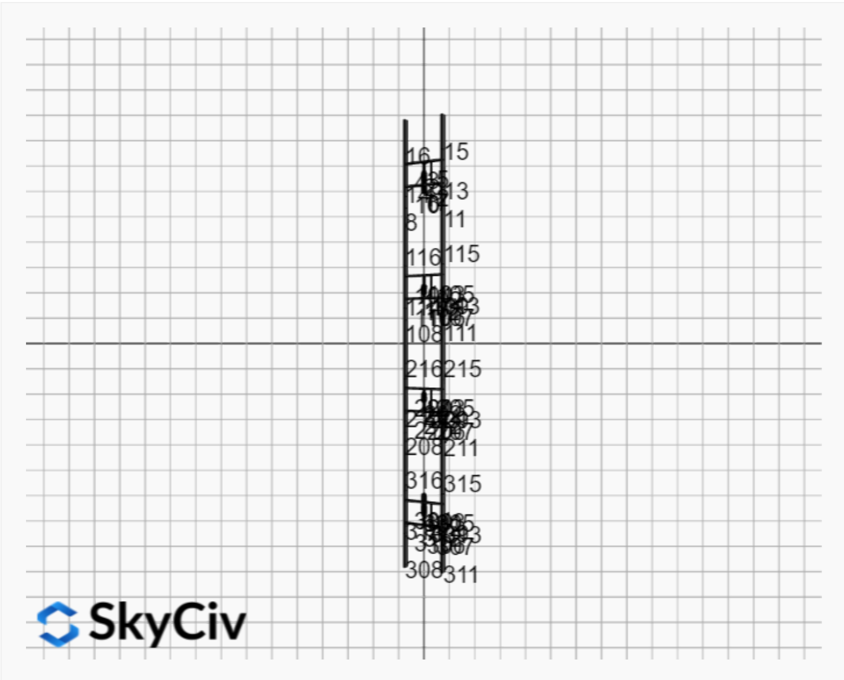
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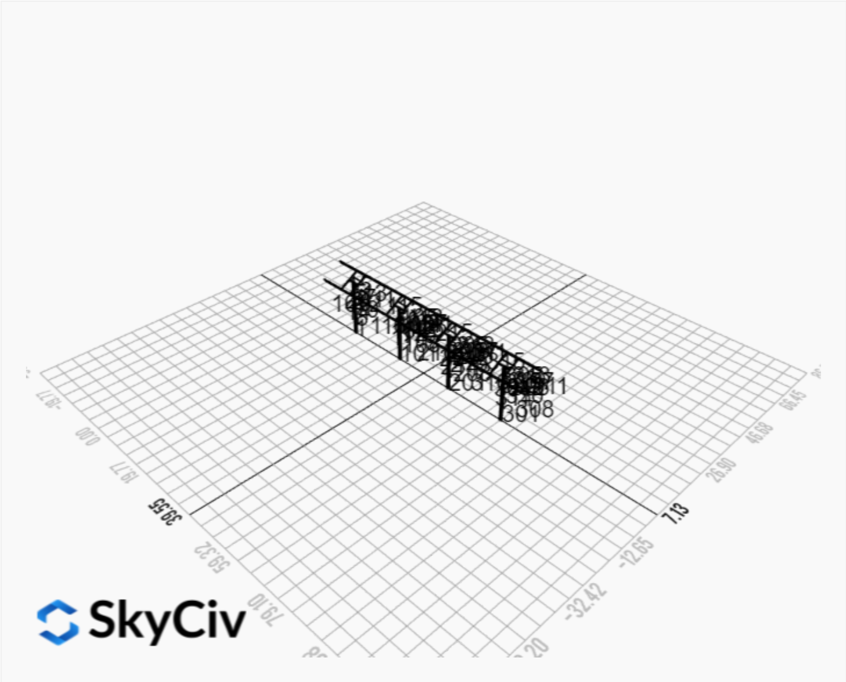
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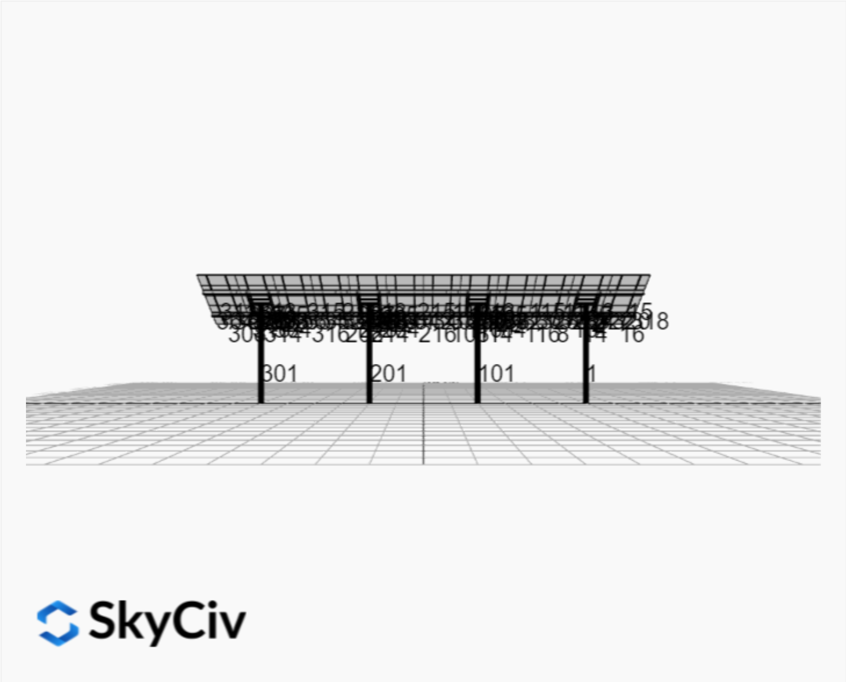
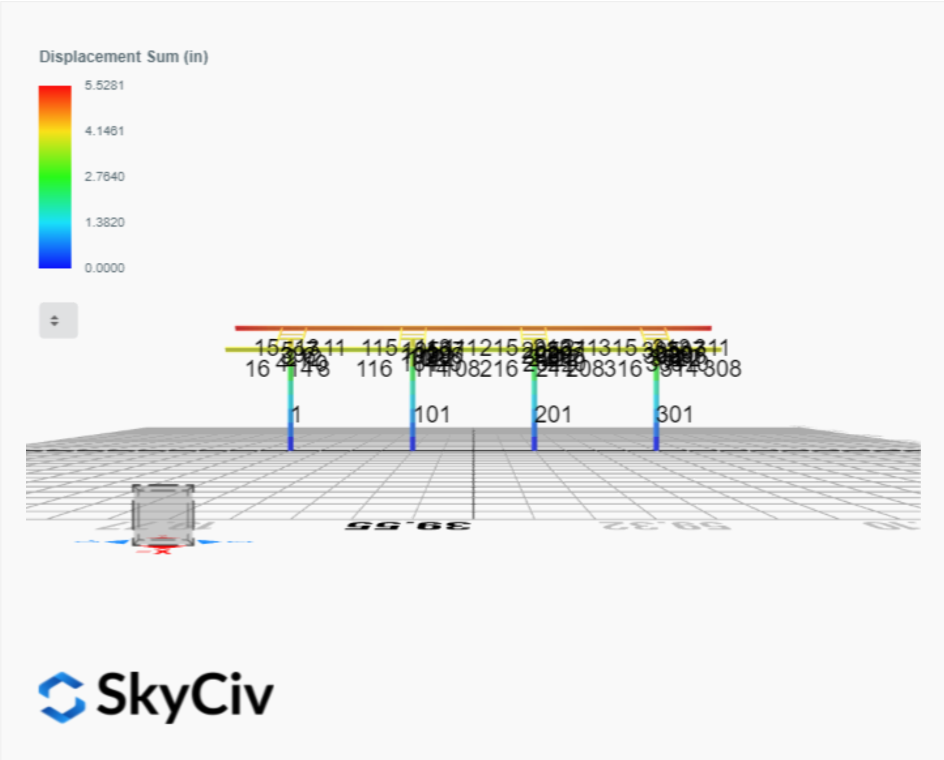
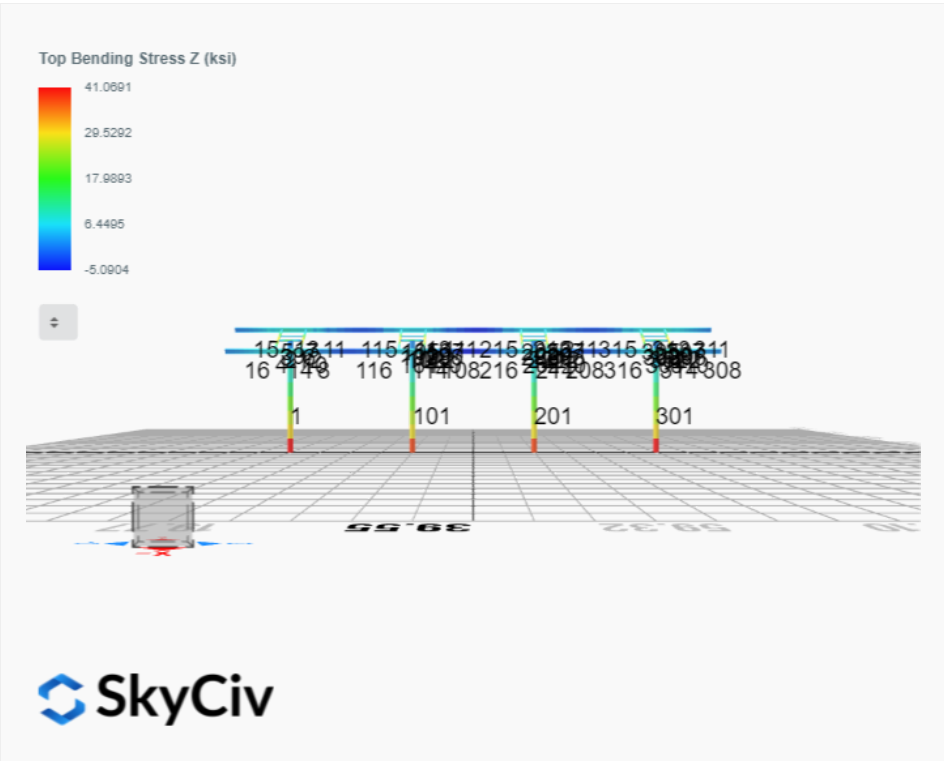
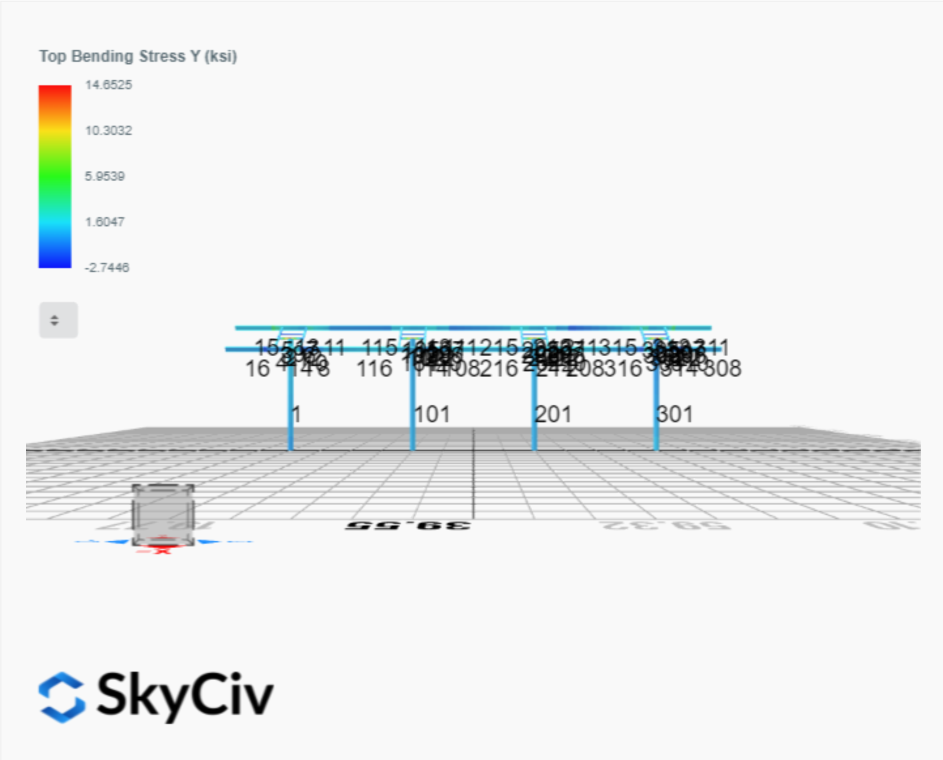
-12.65
26.90
46.58
66.45
59.32
79.10
0.00
19.77
-19.77


301
201
101
1

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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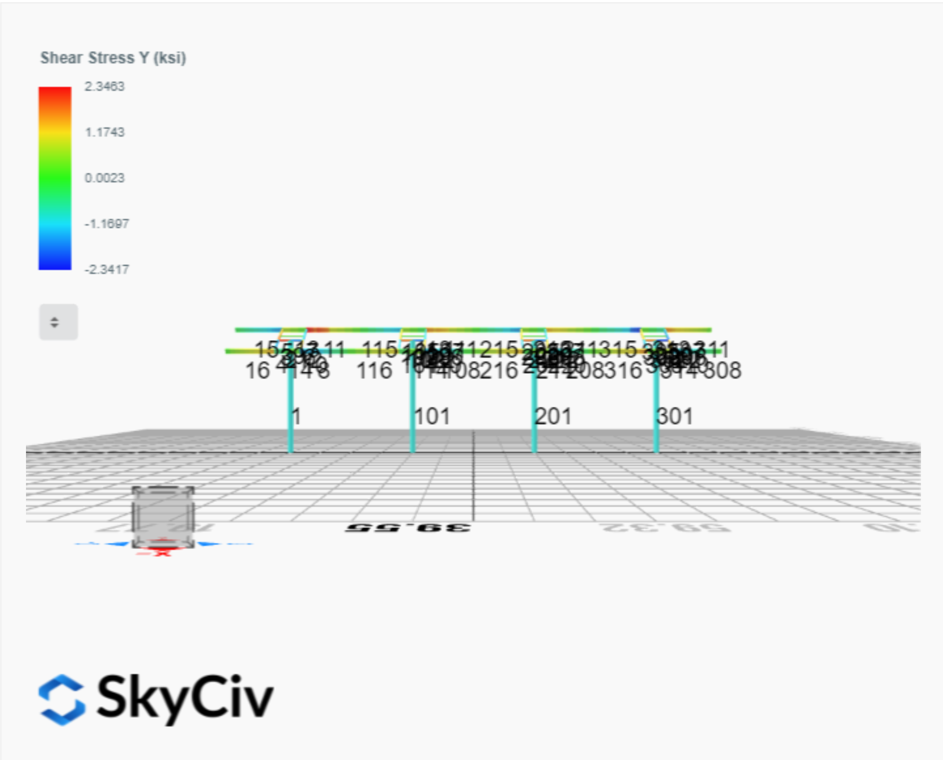
5.9539
1.6047
-2.7446
1
101
201
301


Shear Stress Y (ksi)
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1.1743
0.0023
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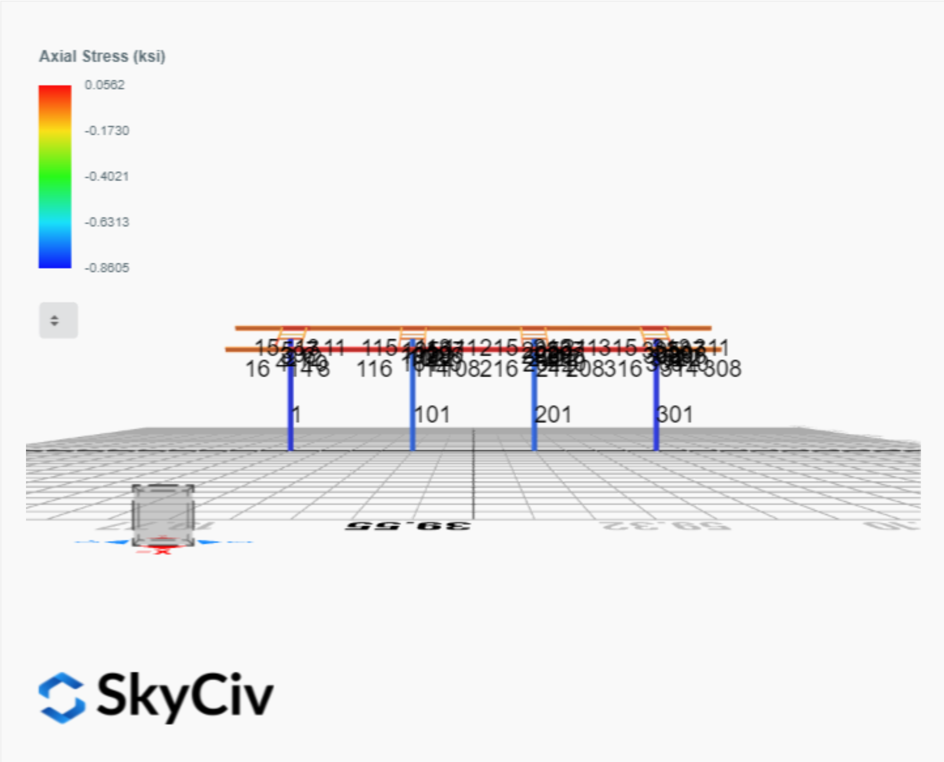
-2.3417
1
101
201
301


Axial Stress (ksi)
0.0562
-0.1730
-0.4021
-0.6313
-0.8605
1
101
201
301
39.55
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	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 2. D + L	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 3. D + (S or Lr or R)	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 3. D + (S or Lr or R)	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 5b. D + 0.7E	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0188	3.0308	-0.0326	-0.1850	0.0896	0.3475
ULS: 8. 0.6D + 0.7E	-0.0113	1.8185	-0.0196	-0.1110	0.0538	0.2085
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.0912	10.1368	-0.1692	-0.9288	0.6221	77.3344
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.0912	10.1368	-0.1692	-0.9288	0.6221	77.3344
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4818	-3.0513	0.0872	0.5029	-0.3619	-61.0541
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8916	-2.0262	0.0758	0.4549	-0.3366	-64.9634
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0731	8.3603	-0.1350	-0.7429	0.4890	58.0877
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0731	8.3603	-0.1350	-0.7429	0.4890	58.0877
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6066	-1.5307	0.0572	0.3309	-0.2490	-45.7037
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1640	-0.7619	0.0487	0.2950	-0.2300	-48.6357
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0731	8.3603	-0.1350	-0.7429	0.4890	58.0877
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0731	8.3603	-0.1350	-0.7429	0.4890	58.0877
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6066	-1.5307	0.0572	0.3309	-0.2490	-45.7037
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1640	-0.7619	0.0487	0.2950	-0.2300	-48.6357
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.0837	8.9245	-0.1561	-0.8548	0.5862	77.1954
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.0837	8.9245	-0.1561	-0.8548	0.5862	77.1954
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4893	-4.2636	0.1002	0.5769	-0.3977	-61.1931
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8991	-3.2385	0.0888	0.5290	-0.3724	-65.1024

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	15.4828
Shear X	-6.8092
Shear Z	-0.2667
Moment X	-1.4488
Moment Y (Twist)	0.9948
Moment Z	130.1334

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.1368
Shear X	-4.0912
Shear Z	-0.1692
Moment X	-0.9288
Moment Y (Twist)	0.6221
Moment Z	77.3344

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	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 2. D + L	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 3. D + (S or Lr or R)	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 3. D + (S or Lr or R)	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 5b. D + 0.7E	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0188	2.9613	0.0031	0.0178	-0.0097	-0.2956
ULS: 8. 0.6D + 0.7E	0.0113	1.7768	0.0019	0.0107	-0.0058	-0.1774
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9086	9.7116	0.0208	0.1164	-0.0526	73.9516
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.9086	9.7116	0.0208	0.1164	-0.0526	73.9516
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.3753	-2.8333	-0.0105	-0.0615	0.0244	-59.3930
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8226	-1.8788	-0.0038	-0.0252	0.0009	-63.3216
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9268	8.0240	0.0164	0.0917	-0.0419	55.3898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9268	8.0240	0.0164	0.0917	-0.0419	55.3898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5362	-1.3846	-0.0071	-0.0417	0.0159	-44.6187
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1216	-0.6687	-0.0020	-0.0145	-0.0017	-47.5651
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9268	8.0240	0.0164	0.0917	-0.0419	55.3898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9268	8.0240	0.0164	0.0917	-0.0419	55.3898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5362	-1.3846	-0.0071	-0.0417	0.0159	-44.6187
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1216	-0.6687	-0.0020	-0.0145	-0.0017	-47.5651
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9161	8.5271	0.0195	0.1092	-0.0488	74.0699
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.9161	8.5271	0.0195	0.1092	-0.0488	74.0699
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.3678	-4.0178	-0.0117	-0.0687	0.0283	-59.2748
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8151	-3.0633	-0.0050	-0.0324	0.0048	-63.2034

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	14.8008
Shear X	-6.5457
Shear Z	0.0339
Moment X	0.1911
Moment Y (Twist)	0.0884
Moment Z	124.7599

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	9.7116
Shear X	-3.9161
Shear Z	0.0208
Moment X	0.1164
Moment Y (Twist)	0.0526
Moment Z	74.0699

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	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 2. D + L	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 3. D + (S or Lr or R)	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 3. D + (S or Lr or R)	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 5b. D + 0.7E	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0188	2.9614	-0.0031	-0.0178	0.0095	-0.2954
ULS: 8. 0.6D + 0.7E	0.0113	1.7768	-0.0019	-0.0107	0.0057	-0.1772
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9085	9.7117	-0.0209	-0.1186	0.0553	73.9482
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.9085	9.7117	-0.0209	-0.1186	0.0553	73.9482
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.3753	-2.8335	0.0104	0.0609	-0.0244	-59.3938
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8226	-1.8790	0.0036	0.0218	0.0002	-63.3237
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9267	8.0241	-0.0165	-0.0934	0.0438	55.3873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9267	8.0241	-0.0165	-0.0934	0.0438	55.3873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5362	-1.3848	0.0070	0.0412	-0.0159	-44.6192
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1217	-0.6689	0.0019	0.0119	0.0025	-47.5666

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	-2.9267	8.0241	-0.0165	-0.0934	0.0438	55.3873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9267	8.0241	-0.0165	-0.0934	0.0438	55.3873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5362	-1.3848	0.0070	0.0412	-0.0159	-44.6192
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1217	-0.6689	0.0019	0.0119	0.0025	-47.5666
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9160	8.5272	-0.0197	-0.1115	0.0514	74.0664
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.9160	8.5272	-0.0197	-0.1115	0.0514	74.0664
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.3678	-4.0180	0.0117	0.0680	-0.0282	-59.2756
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8151	-3.0635	0.0049	0.0289	-0.0036	-63.2055

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	14.8026
Shear X	-6.5455
Shear Z	-0.0336
Moment X	-0.1874
Moment Y (Twist)	0.0847
Moment Z	124.7669

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	9.7117
Shear X	-3.9160
Shear Z	-0.0209
Moment X	-0.1186
Moment Y (Twist)	0.0553
Moment Z	74.0664

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	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 2. D + L	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 3. D + (S or Lr or R)	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 3. D + (S or Lr or R)	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 5b. D + 0.7E	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0188	3.0308	0.0326	0.1850	-0.0897	0.3479
ULS: 8. 0.6D + 0.7E	-0.0113	1.8185	0.0195	0.1110	-0.0538	0.2087
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.0914	10.1366	0.1693	0.9277	-0.6204	77.3348
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.0914	10.1366	0.1693	0.9277	-0.6204	77.3348
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4818	-3.0512	-0.0871	-0.5027	0.3617	-61.0532
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.8916	-2.0263	-0.0756	-0.4564	0.3366	-64.9598
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0733	8.3602	0.1351	0.7420	-0.4877	58.0880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0733	8.3602	0.1351	0.7420	-0.4877	58.0880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6066	-1.5307	-0.0572	-0.3308	0.2489	-45.7029
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1640	-0.7620	-0.0486	-0.2960	0.2300	-48.6329
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0733	8.3602	0.1351	0.7420	-0.4877	58.0880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.0733	8.3602	0.1351	0.7420	-0.4877	58.0880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6066	-1.5307	-0.0572	-0.3308	0.2489	-45.7029
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.1640	-0.7620	-0.0486	-0.2960	0.2300	-48.6329
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.0839	8.9243	0.1562	0.8537	-0.5845	77.1956
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.0839	8.9243	0.1562	0.8537	-0.5845	77.1956
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4893	-4.2635	-0.1001	-0.5767	0.3976	-61.1923
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.8991	-3.2386	-0.0887	-0.5304	0.3725	-65.0990

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	15.4823
Shear X	-6.8088
Shear Z	0.2663
Moment X	1.4490
Moment Y (Twist)	0.9956
Moment Z	130.1311

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

Result	Value (kip, kip-ft)
Axial	10.1366
Shear X	-4.0914
Shear Z	0.1693
Moment X	0.9277
Moment Y (Twist)	0.6204
Moment Z	77.3348

Project Details

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

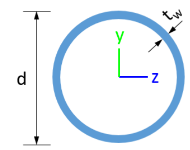
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

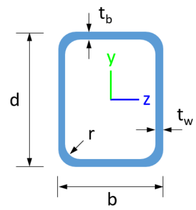
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

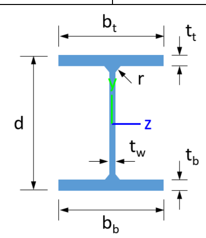
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
11	10in Pipe Sch 40	10.75	0.36					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	38.15	38.15	18.17	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
4	17	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.64,1.67,1.67,1.65,1.77,1.67,1.67,1.65,1.77,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.66	300	200	1
8	20	1.33	1.33	2.05	2.10,2.05,2.05,2.05,2.05,1.98,1.20,1.20,1.29,2.26,1.20,1.20,1.29,2.26,1.34,1.34,1.42,2.26,1.34,1.34,1.42,2.26,1.34,1.34,1.52,2.24	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.66,1.61,1.67,1.67,1.65,1.73,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
11	20	1.33	1.33	2.05	1.55,1.58,1.58,1.58,1.58,1.64,1.40,1.40,1.07,1.65,1.40,1.40,1.07,1.65,1.52,1.52,1.88,1.82,1.52,1.52,1.88,1.82,1.08,1.08,1.52,2.01	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.08,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.10,1.10,1.08,1.08,1.10,1.10,1.08,1.08,1.09,1.12,1.08,1.08,1.09,1.12,1.08,1.08,1.10,1.10	300	200	1
14	20	4.88	4.00	7.50	1.17,1.15,1.15,1.15,1.15,1.12,1.07,1.07,1.10,2.35,1.07,1.07,1.10,2.35,1.08,1.08,1.09,4.09,1.08,1.08,1.09,4.09,1.07,1.07,1.10,1.68	300	200	1
15	20	12.60	12.60	6.00	2.36,2.33,2.33,2.33,2.33,2.30,2.08,2.08,1.83,1.97,2.08,2.08,1.83,1.97,2.01,2.01,1.72,1.74,2.01,2.01,1.72,1.74,2.19,2.19,2.01,2.18	300	200	1
16	20	12.60	12.60	6.00	2.44,2.45,2.45,2.45,2.45,2.46,2.25,2.25,2.14,2.25,2.25,2.25,2.14,2.25,2.31,2.31,1.94,2.27,2.31,2.31,1.94,2.27,2.24,2.24,2.19,2.38	300	200	1
101	11	38.15	38.15	18.17	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.75,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
105	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1

108	20	1.33	1.33	2.05	2.13,2.12,2.12,2.12,2.12,2.10,1.45,1.45,1.02,2.24,1.45,1.45,1.02,2.24,1.54,1.54,1.58,2.27,1.54,1.54,1.58,2.27,1.60,1.60,1.35,2.22	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.75,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
111	20	1.33	1.33	2.05	1.93,1.96,1.96,1.96,1.96,2.02,1.15,1.15,1.74,1.04,1.15,1.15,1.74,1.04,1.26,1.26,2.11,2.11,1.26,1.26,2.11,2.11,1.73,1.73,1.03,2.02	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.05	300	200	1
114	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.05,2.60,1.06,1.06,1.05,2.60,1.06,1.06,1.05,4.25,1.06,1.06,1.05,4.25,1.06,1.06,1.05,1.77	300	200	1
115	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.17	300	200	1
116	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.17,2.27,1.17,1.17,1.17,2.27,1.17,1.17,1.18,1.52,1.17,1.17,1.18,1.52,1.17,1.17,1.17,1.80	300	200	1
201	11	38.15	38.15	18.17	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.75,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
205	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
208	20	1.33	1.33	2.05	2.16,2.15,2.15,2.15,2.15,2.14,2.02,2.02,1.92,2.25,2.02,2.02,1.92,2.25,1.97,1.97,2.08,2.26,1.97,1.97,2.08,2.26,2.06,2.06,1.10,2.24	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.75,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65	300	200	1
211	20	1.33	1.33	2.05	2.35,2.36,2.36,2.36,2.36,2.38,2.45,2.45,2.17,2.38,2.45,2.45,2.17,2.38,2.60,2.60,2.19,2.27,2.60,2.60,2.19,2.27,2.38,2.38,2.15,2.88	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.05	300	200	1
214	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.05,2.60,1.06,1.06,1.05,2.60,1.06,1.06,1.05,4.25,1.06,1.06,1.05,4.25,1.06,1.06,1.05,1.77	300	200	1
215	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.14,1.15,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.15,1.15,1.15	300	200	1
216	20	6.63	6.63	10.20	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.21,1.14,1.14,1.14,1.21,1.14,1.14,1.14,1.36,1.14,1.14,1.14,1.36,1.14,1.14,1.14,1.13	300	200	1
301	11	38.15	38.15	18.17	-	300	200	1

302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
304	17	2.44	2.44	3.75	1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.66,1.61,1.67,1.67,1.65,1.73,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
305	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
307	17	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
308	20	12.60	12.60	6.00	2.44,2.45,2.45,2.45,2.46,2.25,2.25,2.14,2.25,2.25,2.25,2.14,2.25,2.31,2.31,1.94,2.27,2.31,2.31,1.94,2.27,2.24,2.24,2.19,2.38	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.64,1.67,1.67,1.65,1.77,1.67,1.67,1.65,1.77,1.67,1.67,1.66,1.65	300	200	1
311	20	12.60	12.60	6.00	2.36,2.33,2.33,2.33,2.30,2.08,2.08,1.83,1.97,2.08,2.08,1.83,1.97,2.01,2.01,1.72,1.74,2.01,2.01,1.72,1.74,2.19,2.19,2.01,2.18	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.10,1.10,1.08,1.08,1.10,1.10,1.08,1.08,1.09,1.12,1.08,1.08,1.09,1.12,1.08,1.08,1.10,1.10	300	200	1
314	20	4.88	4.00	7.50	1.17,1.15,1.15,1.15,1.15,1.12,1.07,1.07,1.09,2.35,1.07,1.07,1.09,2.35,1.08,1.08,1.09,4.09,1.08,1.08,1.09,4.09,1.07,1.07,1.10,1.68	300	200	1
315	20	6.63	6.63	10.20	1.29,1.29,1.29,1.29,1.29,1.26,1.26,1.43,1.45,1.26,1.26,1.43,1.45,1.28,1.28,1.42,1.45,1.28,1.28,1.42,1.45,1.27,1.27,1.41,1.43	300	200	1
316	20	6.63	6.63	10.20	1.31,1.31,1.31,1.31,1.31,1.29,1.29,1.42,2.76,1.29,1.29,1.42,2.76,1.33,1.33,1.43,1.30,1.33,1.33,1.43,1.30,1.29,1.29,1.41,2.11	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	173.26	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	116.35	33.01	6.46	56.26	44.91
14	159.30	116.35	32.70	6.46	56.26	44.91
15	159.30	21.54	46.90	6.46	56.26	44.91
16	159.30	21.54	46.90	6.46	56.26	44.91
101	535.87	173.26	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95

103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	32.09	6.46	56.26	44.91
114	159.30	116.35	32.09	6.46	56.26	44.91
115	159.30	75.13	22.53	6.46	56.26	44.91
116	159.30	75.13	22.34	6.46	56.26	44.91
201	535.87	173.26	147.68	147.68	160.76	160.76
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	32.09	6.46	56.26	44.91
214	159.30	116.35	32.09	6.46	56.26	44.91
215	159.30	75.13	21.96	6.46	56.26	44.91
216	159.30	75.13	21.76	6.46	56.26	44.91
301	535.87	173.26	147.68	147.68	160.76	160.76
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	21.54	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	21.54	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	33.01	6.46	56.26	44.91
314	159.30	116.35	32.70	6.46	56.26	44.91
315	159.30	75.13	24.27	6.46	56.26	44.91
316	159.30	75.13	24.84	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.088	0.881	0.024	0.045	0.002	0.936	#13	0.623	Not Required	Pass
2	0.001	0.557	0.217	0.113	0.048	0.761	#13	0.036	Not Required	Pass
3	0.003	0.796	0.084	0.080	0.051	0.880	#13	0.046	Not Required	Pass
4	0.003	0.797	0.061	0.070	0.014	0.810	#13	0.082	Not Required	Pass

4	0.003	0.797	0.061	0.079	0.014	0.819	#13	0.082	Not Required	Pass
5	0.003	0.492	0.061	0.079	0.024	0.546	#13	0.076	Not Required	Pass
6	0.002	0.678	0.032	0.067	0.020	0.710	#13	0.046	Not Required	Pass
7	0.002	0.421	0.045	0.068	0.012	0.430	#13	0.076	Not Required	Pass
8	0.002	0.059	0.049	0.046	0.005	0.102	#13	0.102	Not Required	Pass
9	0.006	0.097	0.052	0.003	0.001	0.150	#13	0.206	Not Required	Pass
10	0.002	0.686	0.050	0.069	0.013	0.735	#13	0.082	Not Required	Pass
11	0.001	0.106	0.045	0.058	0.005	0.108	#32	0.068	Not Required	Pass
12	0.002	0.418	0.193	0.091	0.039	0.612	#13	0.036	Not Required	Pass
13	0.003	0.364	0.164	0.066	0.013	0.402	#13	0.204	Not Required	Pass
14	0.003	0.340	0.165	0.082	0.008	0.436	#13	0.204	Not Required	Pass
15	0.000	0.127	0.099	0.036	0.005	0.184	#13	0.642	Not Required	Pass
16	0.000	0.134	0.099	0.038	0.005	0.213	#13	0.642	Not Required	Pass
101	0.085	0.845	0.003	0.043	0.000	0.888	#13	0.623	Not Required	Pass
102	0.001	0.448	0.187	0.096	0.042	0.636	#13	0.036	Not Required	Pass
103	0.003	0.701	0.050	0.070	0.031	0.751	#13	0.046	Not Required	Pass
104	0.002	0.694	0.041	0.069	0.009	0.721	#13	0.082	Not Required	Pass
105	0.002	0.435	0.039	0.070	0.010	0.455	#13	0.076	Not Required	Pass
106	0.003	0.713	0.058	0.071	0.035	0.772	#13	0.046	Not Required	Pass
107	0.002	0.442	0.040	0.071	0.011	0.466	#13	0.076	Not Required	Pass
108	0.002	0.077	0.042	0.059	0.005	0.112	#16	0.102	Not Required	Pass
109	0.003	0.067	0.037	0.001	0.000	0.104	#13	0.206	Not Required	Pass
110	0.003	0.711	0.039	0.071	0.009	0.739	#13	0.082	Not Required	Pass
111	0.001	0.038	0.043	0.030	0.005	0.063	#24	0.102	Not Required	Pass
112	0.001	0.465	0.189	0.099	0.042	0.653	#13	0.036	Not Required	Pass
113	0.002	0.224	0.109	0.048	0.006	0.233	#13	0.306	Not Required	Pass
114	0.004	0.218	0.109	0.058	0.006	0.228	#13	0.306	Not Required	Pass
115	0.001	0.182	0.060	0.040	0.005	0.215	#13	0.338	Not Required	Pass
116	0.003	0.188	0.061	0.039	0.005	0.231	#13	0.507	Not Required	Pass
201	0.085	0.845	0.003	0.043	0.000	0.888	#13	0.623	Not Required	Pass
202	0.001	0.465	0.189	0.099	0.042	0.653	#13	0.036	Not Required	Pass
203	0.003	0.713	0.058	0.071	0.035	0.772	#13	0.046	Not Required	Pass
204	0.003	0.711	0.039	0.071	0.009	0.739	#13	0.082	Not Required	Pass
205	0.002	0.442	0.040	0.071	0.011	0.466	#13	0.076	Not Required	Pass
206	0.003	0.701	0.050	0.070	0.031	0.751	#13	0.046	Not Required	Pass
207	0.002	0.435	0.039	0.070	0.010	0.455	#13	0.076	Not Required	Pass
208	0.002	0.096	0.044	0.075	0.005	0.141	#16	0.102	Not Required	Pass
209	0.003	0.067	0.037	0.001	0.000	0.104	#13	0.206	Not Required	Pass
210	0.002	0.694	0.041	0.069	0.009	0.721	#13	0.082	Not Required	Pass
211	0.001	0.048	0.043	0.042	0.005	0.070	#15	0.068	Not Required	Pass
212	0.001	0.448	0.187	0.096	0.042	0.636	#13	0.036	Not Required	Pass
213	0.002	0.224	0.109	0.047	0.006	0.233	#13	0.204	Not Required	Pass
214	0.004	0.218	0.109	0.058	0.006	0.227	#13	0.306	Not Required	Pass
215	0.001	0.262	0.060	0.042	0.005	0.294	#13	0.507	Not Required	Pass
216	0.003	0.279	0.061	0.042	0.005	0.323	#13	0.507	Not Required	Pass
301	0.088	0.881	0.024	0.045	0.002	0.936	#13	0.623	Not Required	Pass
302	0.002	0.418	0.193	0.091	0.039	0.612	#13	0.036	Not Required	Pass
303	0.002	0.678	0.032	0.067	0.020	0.710	#13	0.046	Not Required	Pass
304	0.002	0.686	0.050	0.069	0.013	0.735	#13	0.082	Not Required	Pass
305	0.002	0.421	0.045	0.068	0.012	0.430	#13	0.076	Not Required	Pass
306	0.003	0.796	0.084	0.080	0.051	0.880	#13	0.046	Not Required	Pass
307	0.003	0.492	0.061	0.079	0.024	0.546	#13	0.076	Not Required	Pass
308	0.000	0.134	0.099	0.038	0.005	0.213	#13	0.642	Not Required	Pass
309	0.006	0.097	0.052	0.003	0.001	0.150	#13	0.206	Not Required	Pass

310	0.003	0.796	0.061	0.079	0.014	0.819	#13	0.082	Not Required	Pass
311	0.000	0.127	0.099	0.036	0.005	0.184	#13	0.642	Not Required	Pass
312	0.001	0.557	0.217	0.113	0.048	0.761	#13	0.036	Not Required	Pass
313	0.003	0.360	0.164	0.067	0.013	0.402	#13	0.204	Not Required	Pass
314	0.003	0.340	0.165	0.082	0.008	0.436	#13	0.306	Not Required	Pass
315	0.001	0.177	0.060	0.044	0.005	0.210	#13	0.338	Not Required	Pass
316	0.003	0.167	0.061	0.046	0.005	0.227	#13	0.507	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

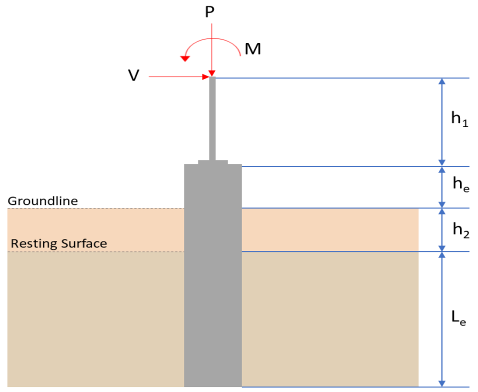
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 9\ \mathrm{ft}$ - 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)	9.712	14.801
V_x (kip)	-3.916	-6.546
V_z (kip)	0.021	0.034
M_x (kipft)	0.116	0.191
M_z (kipft)	74.070	124.760

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,

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

$$H_o = \frac{(-3.916\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.62357\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(74.07\ \mathrm{kipft}) + ((-3.916\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.795\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 8.5447\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.116\ \mathrm{kipft}) + ((0.021\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.018471\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.1976\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.5447\ \mathrm{ft}), (1.1976\ \mathrm{ft})]$$

$$L_{e,req} = 8.545\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 9\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.545\ \mathrm{ft})}{(9\ \mathrm{ft})}$$

$$Ratio = 0.94944$$

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

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

$$q = \frac{(9.712\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.607\ \mathrm{kip/ft}^2$$

$q = 0.607\ \mathrm{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.607\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.3035$$

Status: **PASS**
Ratio: **0.300**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.62357\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.795\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.795\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (11.795\ \mathrm{kipft/ft})) + (4 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.1806\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.795\ \mathrm{kipft/ft})) + (3 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^{\ 2}}{(9\ \mathrm{ft})^2 \times [(3 \times (11.795\ \mathrm{kipft/ft})) + (2 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$

$$p = 0.35284\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (11.795\ \mathrm{kipft/ft})) + ((-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$

$$s = 1.3316\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1806\ \mathrm{ft})}{2}$$

$$p_a = 0.46355\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.35284\ \mathrm{kip/ft^2}\right)}{\left(0.46355\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.76117$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.3316\ \mathrm{kip/ft^2})}{(1.35\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.9864$$

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

Considering z-direction:

$H_o = 0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.018471\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.018471\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (0.018471\ \mathrm{kipft/ft})) + (4 \times (0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.3905\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.018471\ \mathrm{kipft/ft})) + (3 \times (0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^2}{(9\ \mathrm{ft})^2 \times [(3 \times (0.018471\ \mathrm{kipft/ft})) + (2 \times (0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$

$$p = 0.0021587\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.018471\ \mathrm{kipft/ft})) + ((0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$

$$s = 0.0049658\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.3905\ \mathrm{ft})}{2}$$

$$p_a = 0.47929\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0021587\ \mathrm{kip/ft^2})}{(0.47929\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.004504$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

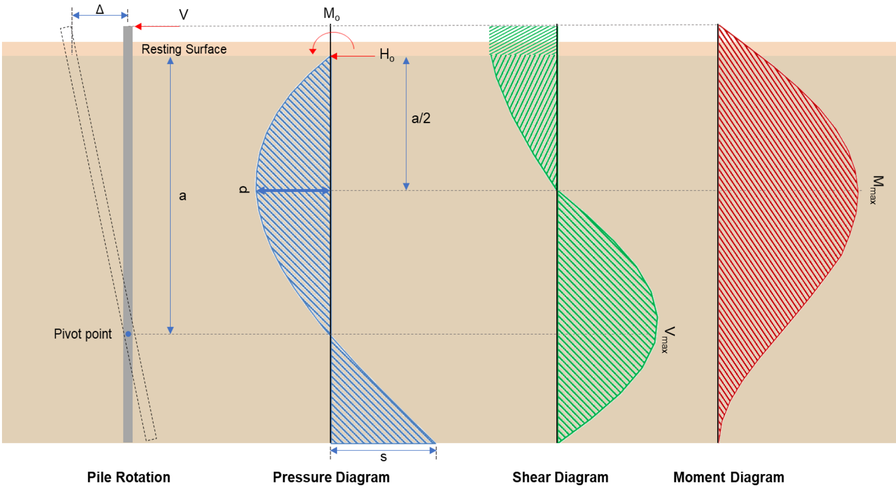
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0049658\ \mathrm{kip/ft^2})}{(1.35\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0036784$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.546\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0424\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(124.76\ \mathrm{kipft}) + ((-6.546\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 19.866\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.866\ \mathrm{kipft/ft})}{(-1.0424\ \mathrm{kip/ft})}$$

$$E = 19.059\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.866\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-1.0424\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (19.866\ \mathrm{kipft/ft})) + (4 \times (-1.0424\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.1796\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.0424\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.059\ \mathrm{ft})}{(9\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1796\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.059\ \mathrm{ft})}{(9\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1796\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.378\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.0424 \text{ kip/ft}) \times (48 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(19.059 \text{ ft})}{(9 \text{ ft})} + \frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (19.059 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (19.059 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 79.285 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.034 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.005414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.191 \text{ kipft}) + ((0.034 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.030414 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.030414 \text{ kipft/ft})}{(0.005414 \text{ kip/ft})}$$

$$E = 5.6176 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.030414 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (0.005414 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (0.030414 \text{ kipft/ft})) + (4 \times (0.005414 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.3873 \text{ ft}$$

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

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

$$V_{max} = ((0.005414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.6176 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.3873 \text{ ft})}{(9 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.6176 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.3873 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.038301 \text{ kip}$$

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

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

$$M_{max} = ((0.005414 \text{ kip/ft}) \times (48 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(5.6176 \text{ ft})}{(9 \text{ ft})} + \frac{(6.3873 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.6176 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.3873 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.6176 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.3873 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.15492 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.801 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.104 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.104 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.801\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0055327$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 14.801\text{ kip} \rightarrow 14801\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(14801\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 120.46\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (120.46\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 120.46\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.46\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.38\ \text{kip}$$

Considering x-direction:

$V_{max} = 18.378\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(18.378\ \text{kip})}{(111.38\ \text{kip})}$$

$$Ratio = 0.165$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$V_{max} = 0.038301\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.038301\ \text{kip})}{(111.38\ \text{kip})}$$

$$Ratio = 0.00034388$$

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:** $M_{max} = 79.285 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(79.285 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.31765$$	Status: **PASS** Ratio: **0.320**
	Considering z-direction: $M_{max} = 0.15492 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.15492 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00062065$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

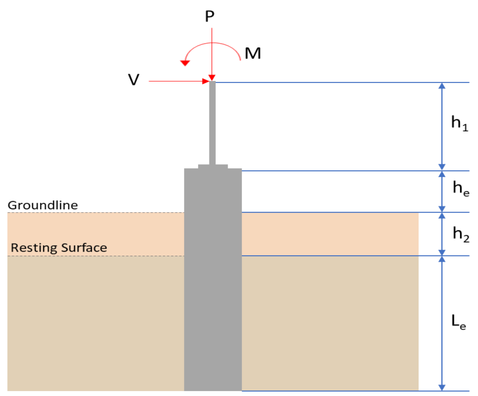
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 9$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	9.712	14.803
V_x (kip)	-3.916	-6.546
V_z (kip)	-0.021	-0.034
M_x (kipft)	-0.119	-0.187
M_z (kipft)	74.066	124.767

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.916 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.62357 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(74.066 \text{ kipft}) + ((-3.916 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.794 \text{ kipft/ft}$$

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:
$L_{e,x} = 8.5445 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.119 \text{ kipft}) + ((-0.021 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.018949 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.0907 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.5445 \text{ ft}), (1.0907 \text{ ft})]$$

$$L_{e,req} = 8.545 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.545 \text{ ft})}{(9 \text{ ft})}$$

$$Ratio = 0.94944$$

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

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

$$q = \frac{(9.712 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.607 \text{ kip/ft}^2$$

$$q = 0.607\ \mathrm{kip/ft}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.607\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.3035$$

Status: **PASS**
Ratio: **0.300**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.62357\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.794\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.794\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (11.794\ \mathrm{kipft/ft})) + (4 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.1806\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.794\ \mathrm{kipft/ft})) + (3 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^{\ 2}}{(9\ \mathrm{ft})^2 \times [(3 \times (11.794\ \mathrm{kipft/ft})) + (2 \times (-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$

$$p = 0.35281\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (11.794\ \mathrm{kipft/ft})) + ((-0.62357\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$

$$s = 1.3315\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1806\ \mathrm{ft})}{2}$$

$$p_a = 0.46355\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.35281\ \mathrm{kip/ft^2}\right)}{\left(0.46355\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.76111$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3315\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.98633$$

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

Considering z-direction:

$H_o = -0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.018949\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.018949\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (0.018949\ \mathrm{kipft/ft})) + (4 \times (-0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.3857\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.018949\ \mathrm{kipft/ft})) + (3 \times (-0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^2}{(9\ \mathrm{ft})^2 \times [(3 \times (0.018949\ \mathrm{kipft/ft})) + (2 \times (-0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$

$$p = -0.00058141\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.018949\ \mathrm{kipft/ft})) + ((-0.0033439\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$

$$s = 0.00057797\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.3857\ \mathrm{ft})}{2}$$

$$p_a = 0.47893\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00058141\ \mathrm{kip/ft^2}\right)}{\left(0.47893\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.001214$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

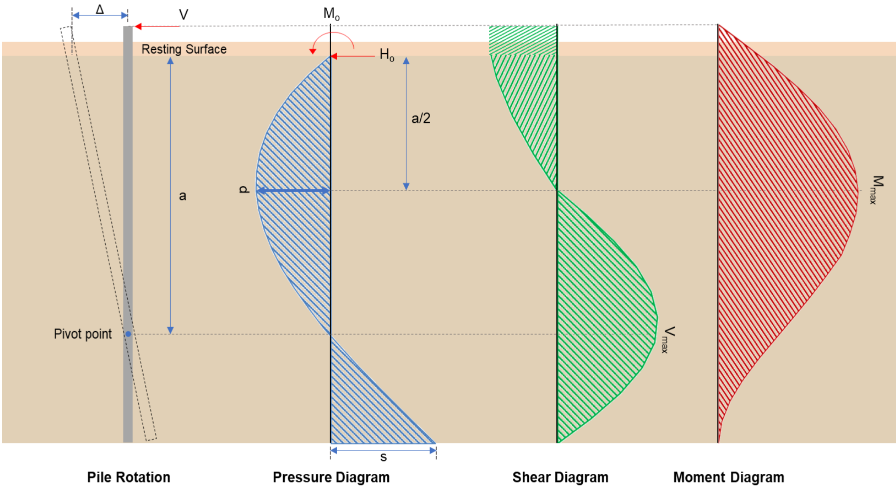
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00057797\ \mathrm{kip/ft^2})}{(1.35\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.00042812$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.546\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0424\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(124.77\ \mathrm{kipft}) + ((-6.546\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 19.867\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.867\ \mathrm{kipft/ft})}{(-1.0424\ \mathrm{kip/ft})}$$

$$E = 19.06\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.867\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-1.0424\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (19.867\ \mathrm{kipft/ft})) + (4 \times (-1.0424\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.1796\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.0424\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.06\ \mathrm{ft})}{(9\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1796\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.06\ \mathrm{ft})}{(9\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1796\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.379\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.0424 \text{ kip/ft}) \times (48 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(19.06 \text{ ft})}{(9 \text{ ft})} + \frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (19.06 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (19.06 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.1796 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 79.289 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.034 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.005414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.187 \text{ kipft}) + ((-0.034 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.029777 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.029777 \text{ kipft/ft})}{(-0.005414 \text{ kip/ft})}$$

$$E = 5.5 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.029777 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (-0.005414 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (0.029777 \text{ kipft/ft})) + (4 \times (-0.005414 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.3913 \text{ ft}$$

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

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

$$V_{max} = ((-0.005414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.5 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.3913 \text{ ft})}{(9 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.5 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.3913 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.037804 \text{ kip}$$

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

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

$$M_{max} = ((-0.005414 \text{ kip/ft}) \times (48 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(5.5 \text{ ft})}{(9 \text{ ft})} + \frac{(6.3913 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.5 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.3913 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.5 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.3913 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.15269 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.803 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.104 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.104 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.803\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0055335$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 14.803\text{ kip} \rightarrow 14803\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(14803\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 120.46\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (120.46\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 120.46\text{ kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\ b_w\ d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$	
	A_v - Ties rebar area, $$A_v = \frac{\pi\ d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\ A_v\ f_{ywk}\ d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$	
	V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.46\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 111.38\ \text{kip}$$	
	Considering x-direction: $V_{max} = 18.379\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(18.379\ \text{kip})}{(111.38\ \text{kip})}$$ $$Ratio = 0.16501$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.037804\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.037804\ \text{kip})}{(111.38\ \text{kip})}$$ $$Ratio = 0.00033942$$	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:** $M_{max} = 79.289 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(79.289 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.31766$$	Status: **PASS** Ratio: **0.320**
	Considering z-direction: $M_{max} = 0.15269 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.15269 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00061172$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

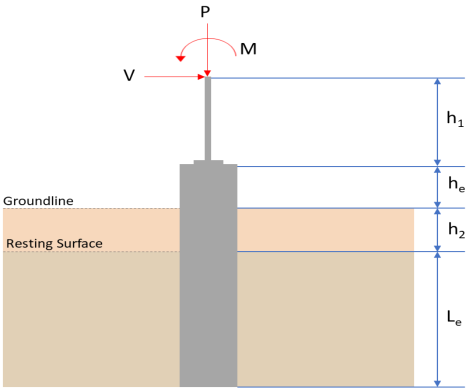
SkyCiv Foundation Design

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
$L = 9.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.137	15.483
V_x (kip)	-4.091	-6.809
V_z (kip)	-0.169	-0.267
M_x (kipft)	-0.929	-1.449
M_z (kipft)	77.334	130.133

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,

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

$$H_o = \frac{(-4.091\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.65143\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(77.334\ \text{kipft}) + ((-4.091\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 12.314\ \text{kipft/ft}$$

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:
$L_{e,x} = 8.6494\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.169\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.026911\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.929\ \text{kipft}) + ((-0.169\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.14793\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0436\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.6494\ \text{ft}), (2.0436\ \text{ft})]$$

$$L_{e,req} = 8.649\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.649\ \text{ft})}{(9.25\ \text{ft})}$$

$$Ratio = 0.93503$$

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

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

$$q = \frac{(10.137\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.63356\ \text{kip/ft}^2$$

$$q = 0.63356 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.63356 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.31678$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.3125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.65143 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 12.314 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.314 \text{ kipft/ft}) \times (9.25 \text{ ft})) + \left(3 \times (-0.65143 \text{ kip/ft}) \times (9.25 \text{ ft})^2\right)}{(6 \times (12.314 \text{ kipft/ft})) + (4 \times (-0.65143 \text{ kip/ft}) \times (9.25 \text{ ft}))}$$

$$a = 6.3563 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (12.314 \text{ kipft/ft})) + (3 \times (-0.65143 \text{ kip/ft}) \times (9.25 \text{ ft}))]^2}{(9.25 \text{ ft})^2 \times [(3 \times (12.314 \text{ kipft/ft})) + (2 \times (-0.65143 \text{ kip/ft}) \times (9.25 \text{ ft}))]}$$

$$p = 0.34236 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (12.314 \text{ kipft/ft})) + ((-0.65143 \text{ kip/ft}) \times (9.25 \text{ ft}))]}{(9.25 \text{ ft})^2}$$

$$s = 1.3045 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.3563 \text{ ft})}{2}$$

$$p_a = 0.47672 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.34236 \text{ kip/ft}^2)}{(0.47672 \text{ kip/ft}^2)}$$

$$Ratio = 0.71815$$

Status: **PASS**
Ratio: **0.720**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.25\ \mathrm{ft})$$

$$p_s = 1.3875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3045\ \mathrm{kip/ft^2}\right)}{\left(1.3875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94019$$

Status: PASS
Ratio: 0.940

Considering z-direction:

$H_o = -0.026911\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.14793\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14793\ \mathrm{kipft/ft}) \times (9.25\ \mathrm{ft})) + \left(3 \times (-0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft})^2\right)}{(6 \times (0.14793\ \mathrm{kipft/ft})) + (4 \times (-0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))}$$

$$a = 6.5742\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.14793\ \mathrm{kipft/ft})) + (3 \times (-0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]^{\,2}}{(9.25\ \mathrm{ft})^2 \times [(3 \times (0.14793\ \mathrm{kipft/ft})) + (2 \times (-0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]}$$

$$p = -0.0038983\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.14793\ \mathrm{kipft/ft})) + ((-0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]}{(9.25\ \mathrm{ft})^2}$$

$$s = 0.0032913\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.5742\ \mathrm{ft})}{2}$$

$$p_a = 0.49307\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0038983\ \mathrm{kip/ft^2}\right)}{\left(0.49307\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0079062$$

Status: PASS
Ratio: -0.010

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.25\ \mathrm{ft})$$

$$p_s = 1.3875\ \mathrm{kip/ft^2}$$

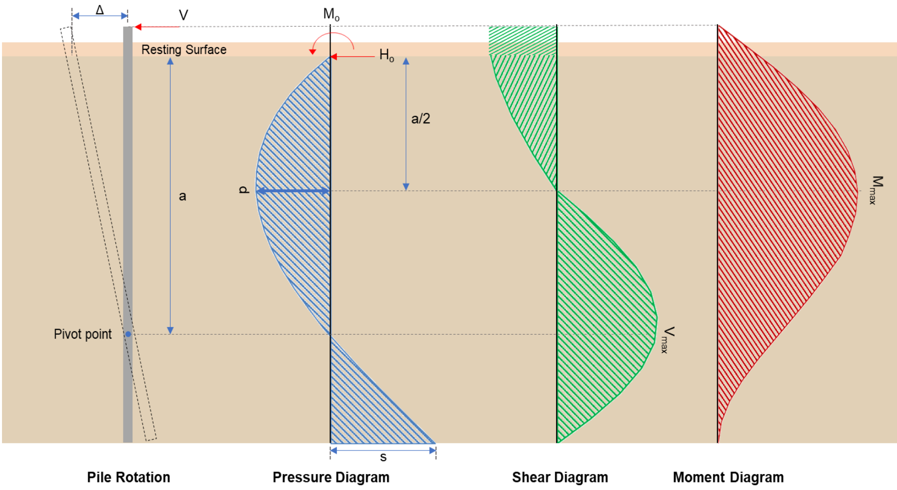
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0032913\ \mathrm{kip/ft^2})}{(1.3875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0023721$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.809\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0842\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(130.13\ \mathrm{kipft}) + ((-6.809\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 20.722\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(20.722\ \mathrm{kipft/ft})}{(-1.0842\ \mathrm{kip/ft})}$$

$$E = 19.112\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (20.722\ \mathrm{kipft/ft}) \times (9.25\ \mathrm{ft})) + \left(3 \times (-1.0842\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft})^2\right)}{(6 \times (20.722\ \mathrm{kipft/ft})) + (4 \times (-1.0842\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))}$$

$$a = 6.3547\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.0842\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.112\ \mathrm{ft})}{(9.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.3547\ \mathrm{ft})}{(9.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.112\ \mathrm{ft})}{(9.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.3547\ \mathrm{ft})}{(9.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.72\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.0842 \text{ kip/ft}) \times (48 \text{ in}) \times (9.25 \text{ ft})) \times \left[\left(\frac{(19.112 \text{ ft})}{(9.25 \text{ ft})} + \frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (19.112 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (19.112 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 82.931 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.267 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.042516 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.449 \text{ kipft}) + ((-0.267 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23073 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.23073 \text{ kipft/ft})}{(-0.042516 \text{ kip/ft})}$$

$$E = 5.427 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23073 \text{ kipft/ft}) \times (9.25 \text{ ft})) + \left(3 \times (-0.042516 \text{ kip/ft}) \times (9.25 \text{ ft})^2\right)}{(6 \times (0.23073 \text{ kipft/ft})) + (4 \times (-0.042516 \text{ kip/ft}) \times (9.25 \text{ ft}))}$$

$$a = 6.5767 \text{ ft}$$

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

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

$$V_{max} = ((-0.042516 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.427 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.5767 \text{ ft})}{(9.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.427 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.5767 \text{ ft})}{(9.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.28959 \text{ kip}$$

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

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

$$M_{max} = ((-0.042516 \text{ kip/ft}) \times (48 \text{ in}) \times (9.25 \text{ ft})) \times \left[\left(\frac{(5.427 \text{ ft})}{(9.25 \text{ ft})} + \frac{(6.5767 \text{ ft})}{2 \times (9.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.427 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.5767 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.427 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.5767 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.1987 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.483 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.082 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.082 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.483\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0057876$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 15.483\ \text{kip} \rightarrow 15483\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(15483\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.55\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.55\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.55\ \text{kip}$$

22.5.1.2	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.55\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 111.44\ \text{kip}$$ **Considering x-direction:** $V_{max} = 18.72\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(18.72\ \text{kip})}{(111.44\ \text{kip})}$$ $$Ratio = 0.16799$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.28959\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.28959\ \text{kip})}{(111.44\ \text{kip})}$$ $$Ratio = 0.0025987$$	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	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ 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:** $M_{max} = 82.931\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(82.931\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.33225$$	Status: **PASS** Ratio: **0.330**
	Considering z-direction: $M_{max} = 1.1987\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1987\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0048027$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

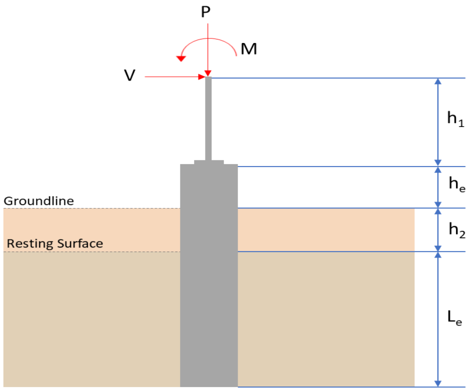
SkyCiv Foundation Design

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
$L = 9.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.137	15.482
V_x (kip)	-4.091	-6.809
V_z (kip)	0.169	0.266
M_x (kipft)	0.928	1.449
M_z (kipft)	77.335	130.131

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,

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

$$H_o = \frac{(-4.091\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.65143\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(77.335 \text{ kipft}) + ((-4.091 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 12.314 \text{ kipft/ft}$$

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:
$L_{e,x} = 8.6494 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.169 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.026911 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.928 \text{ kipft}) + ((0.169 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.14777 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.5135 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.6494 \text{ ft}), (2.5135 \text{ ft})]$$

$$L_{e,req} = 8.649 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.649 \text{ ft})}{(9.25 \text{ ft})}$$

$$Ratio = 0.93503$$

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

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

$$q = \frac{(10.137 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.63356 \text{ kip/ft}^2$$

$q = 0.63356\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.63356\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.31678$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{\left(9.25\ \mathrm{ft}\right)}{\left(48\ \mathrm{in}\right)}$$

$$L/D = 2.3125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.65143\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 12.314\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(12.314\ \mathrm{kipft/ft}\right) \times \left(9.25\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.65143\ \mathrm{kip/ft}\right) \times \left(9.25\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(12.314\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.65143\ \mathrm{kip/ft}\right) \times \left(9.25\ \mathrm{ft}\right)\right)}$$

$$a = 6.3563\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(12.314\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.65143\ \mathrm{kip/ft}\right) \times \left(9.25\ \mathrm{ft}\right)\right)\right]^2}{\left(9.25\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(12.314\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.65143\ \mathrm{kip/ft}\right) \times \left(9.25\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.34237\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(12.314\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.65143\ \mathrm{kip/ft}\right) \times \left(9.25\ \mathrm{ft}\right)\right)\right]}{\left(9.25\ \mathrm{ft}\right)^2}$$

$$s = 1.3045\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(6.3563\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.47672\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.34237\ \mathrm{kip/ft^2}\right)}{\left(0.47672\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71817$$

Status: **PASS**
Ratio: **0.720**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.25\ \mathrm{ft})$$

$$p_s = 1.3875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.3045\ \mathrm{kip/ft^2})}{(1.3875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.94021$$

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

Considering z-direction:

$H_o = 0.026911\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.14777\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14777\ \mathrm{kipft/ft}) \times (9.25\ \mathrm{ft})) + \left(3 \times (0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft})^2\right)}{(6 \times (0.14777\ \mathrm{kipft/ft})) + (4 \times (0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))}$$

$$a = 6.5744\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.14777\ \mathrm{kipft/ft})) + (3 \times (0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]^{\,2}}{(9.25\ \mathrm{ft})^2 \times [(3 \times (0.14777\ \mathrm{kipft/ft})) + (2 \times (0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]}$$

$$p = 0.01667\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.14777\ \mathrm{kipft/ft})) + ((0.026911\ \mathrm{kip/ft}) \times (9.25\ \mathrm{ft}))]}{(9.25\ \mathrm{ft})^2}$$

$$s = 0.03818\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.5744\ \mathrm{ft})}{2}$$

$$p_a = 0.49308\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.01667\ \mathrm{kip/ft^2})}{(0.49308\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.033808$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.25\ \mathrm{ft})$$

$$p_s = 1.3875\ \mathrm{kip/ft^2}$$

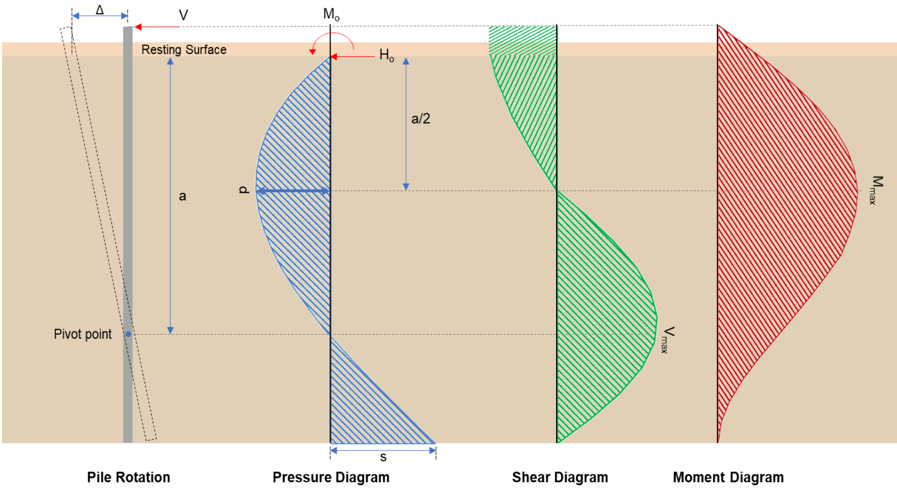
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.03818\ \text{kip/ft}^2)}{(1.3875\ \text{kip/ft}^2)}$$

$$Ratio = 0.027517$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.809\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.0842\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(130.13\ \text{kipft}) + ((-6.809\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 20.721\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(20.721\ \text{kipft/ft})}{(-1.0842\ \text{kip/ft})}$$

$$E = 19.112\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (20.721\ \text{kipft/ft}) \times (9.25\ \text{ft})) + \left(3 \times (-1.0842\ \text{kip/ft}) \times (9.25\ \text{ft})^2\right)}{(6 \times (20.721\ \text{kipft/ft})) + (4 \times (-1.0842\ \text{kip/ft}) \times (9.25\ \text{ft}))}$$

$$a = 6.3547\ \text{ft}$$

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

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

$$V_{max} = ((-1.0842\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.112\ \text{ft})}{(9.25\ \text{ft})} + 3\right) \times \left(\frac{(6.3547\ \text{ft})}{(9.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.112\ \text{ft})}{(9.25\ \text{ft})} + 2\right) \times \left(\frac{(6.3547\ \text{ft})}{(9.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.72\ \text{kip}$$

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

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

$$M_{max} = ((-1.0842 \text{ kip/ft}) \times (48 \text{ in}) \times (9.25 \text{ ft})) \times \left[\left(\frac{(19.112 \text{ ft})}{(9.25 \text{ ft})} + \frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (19.112 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (19.112 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.3547 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 82.93 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.266 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.042357 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.449 \text{ kipft}) + ((0.266 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23073 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.23073 \text{ kipft/ft})}{(0.042357 \text{ kip/ft})}$$

$$E = 5.4474 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23073 \text{ kipft/ft}) \times (9.25 \text{ ft})) + \left(3 \times (0.042357 \text{ kip/ft}) \times (9.25 \text{ ft})^2\right)}{(6 \times (0.23073 \text{ kipft/ft})) + (4 \times (0.042357 \text{ kip/ft}) \times (9.25 \text{ ft}))}$$

$$a = 6.576 \text{ ft}$$

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

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

$$V_{max} = ((0.042357 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.4474 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.576 \text{ ft})}{(9.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5.4474 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.576 \text{ ft})}{(9.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.28916 \text{ kip}$$

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

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

$$M_{max} = ((0.042357 \text{ kip/ft}) \times (48 \text{ in}) \times (9.25 \text{ ft})) \times \left[\left(\frac{(5.4474 \text{ ft})}{(9.25 \text{ ft})} + \frac{(6.576 \text{ ft})}{2 \times (9.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (5.4474 \text{ ft})}{(9.25 \text{ ft})} + 3 \right) \times \left(\frac{(6.576 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5.4474 \text{ ft})}{(9.25 \text{ ft})} + 2 \right) \times \left(\frac{(6.576 \text{ ft})}{2 \times (9.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.1973 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.482 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.082 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.082 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.482\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0057873$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 15.482\ \text{kip} \rightarrow 15482\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(15482\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.55\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.55\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.55\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\ b_w\ d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\ d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\ A_v\ f_{ywk}\ d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.55\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 111.44\ \text{kip}$$ **Considering x-direction:** $V_{max} = 18.72\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(18.72\ \text{kip})}{(111.44\ \text{kip})}$$ $$Ratio = 0.16799$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.28916\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.28916\ \text{kip})}{(111.44\ \text{kip})}$$ $$Ratio = 0.0025948$$	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	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ 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:** $M_{max} = 82.93\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(82.93\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.33225$$	Status: **PASS** Ratio: **0.330**
	Considering z-direction: $M_{max} = 1.1973\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1973\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0047968$$	Status: **PASS** Ratio: **0.000**