Your Project Calculations

Project Name: Bybee Lakes Hope Center

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Bybee%20Lakes%20Hope%20Center&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=1PteyFKJNXvBd460wxOWWLUaH8tDta7hIvuPU1XrOYqRickR5iotxwnUdMBjMves

Array Specification

Product:	Beam
Unique ID:	4P-19.75-6TOP-SD-45-L-5Hx10W-1DD8
Duty Classification:	SD
Module Width:	41.10 in
Module Length:	87.20in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Desired Tilt Angle:	5
Front Edge Clearance:	10
Total Array Height at Tilt:	11.50 ft
Total Frame Length:	74.25 ft
Frame Weight:	2764 lbs
Array Dimensions N/S:	17.33 ft
Array Dimensions E/W:	73.50 ft
Rail Length:	208.00 in
Rail Spacing:	3.63 ft
Rail Check:	Not Checked

Support Specifications

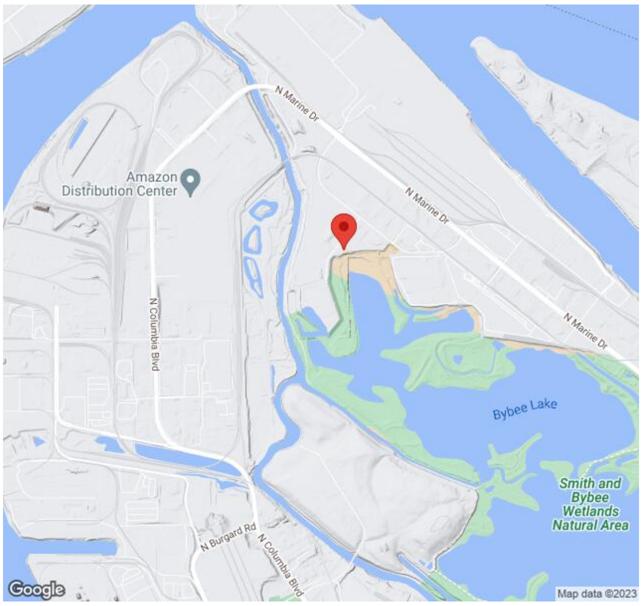
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	10.76 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 6.50 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 6.50 ft
Foundation Volume:	6.938 y^3
Foundation Result:	PASSED
Mount Twist:	0.033691 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	14355 N Bybee Lake Ct, Portland, OR 97217, USA
Wind Speed:	90 mph
Snow Load:	10 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.006048 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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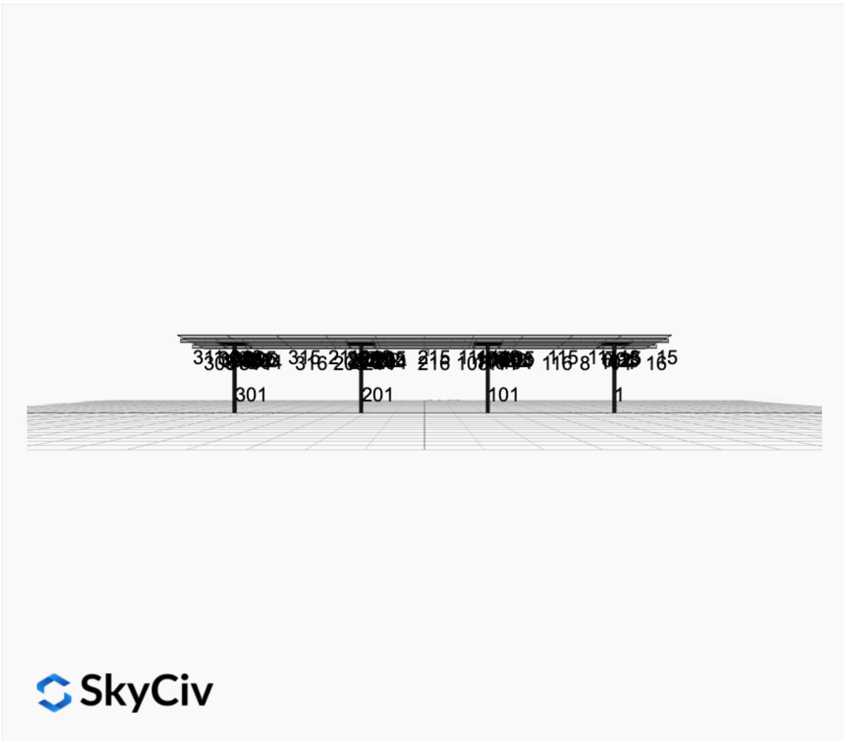
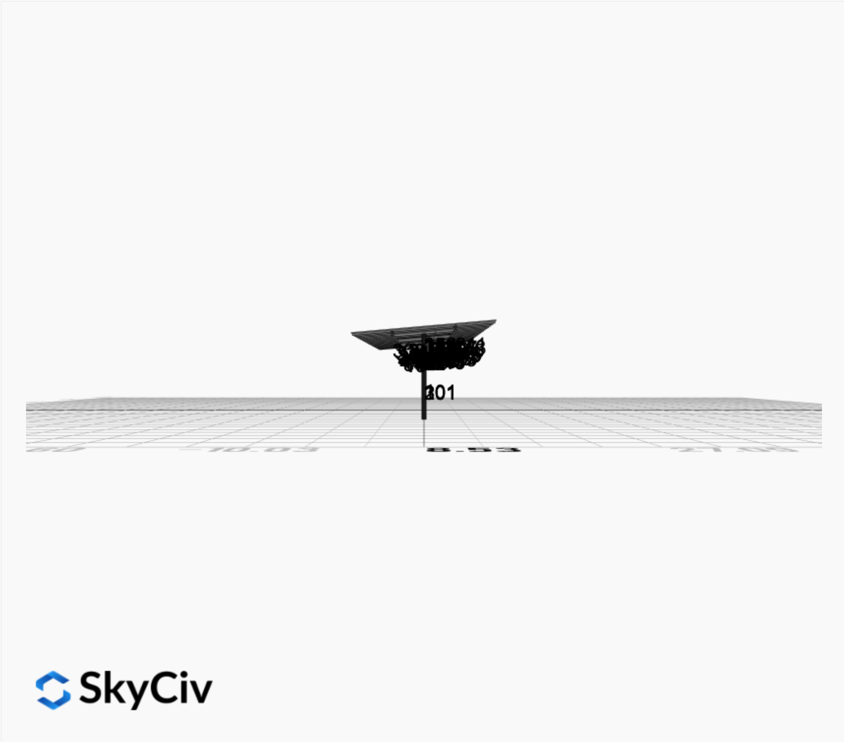
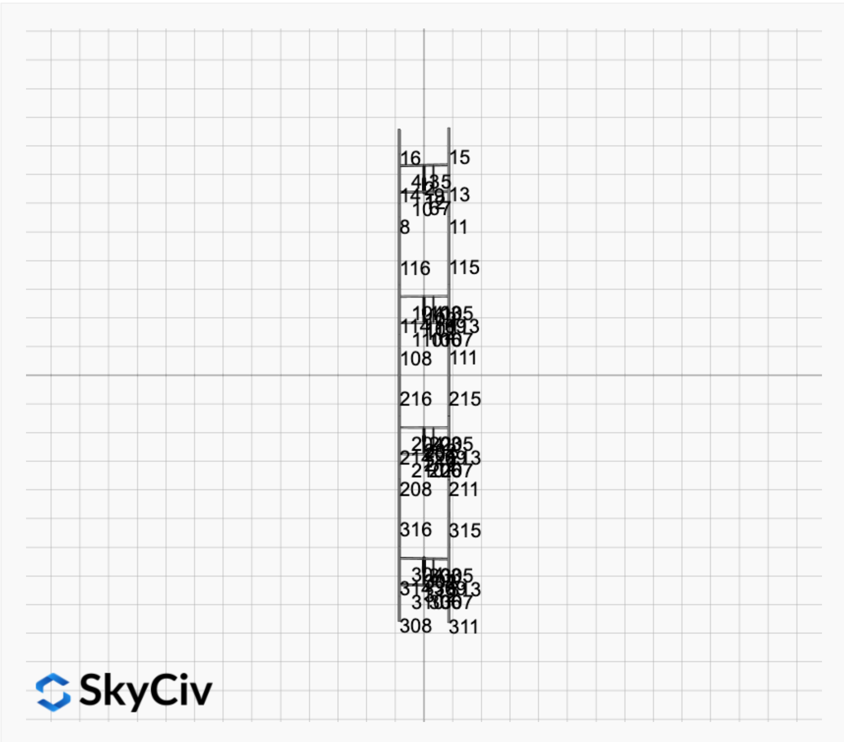
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



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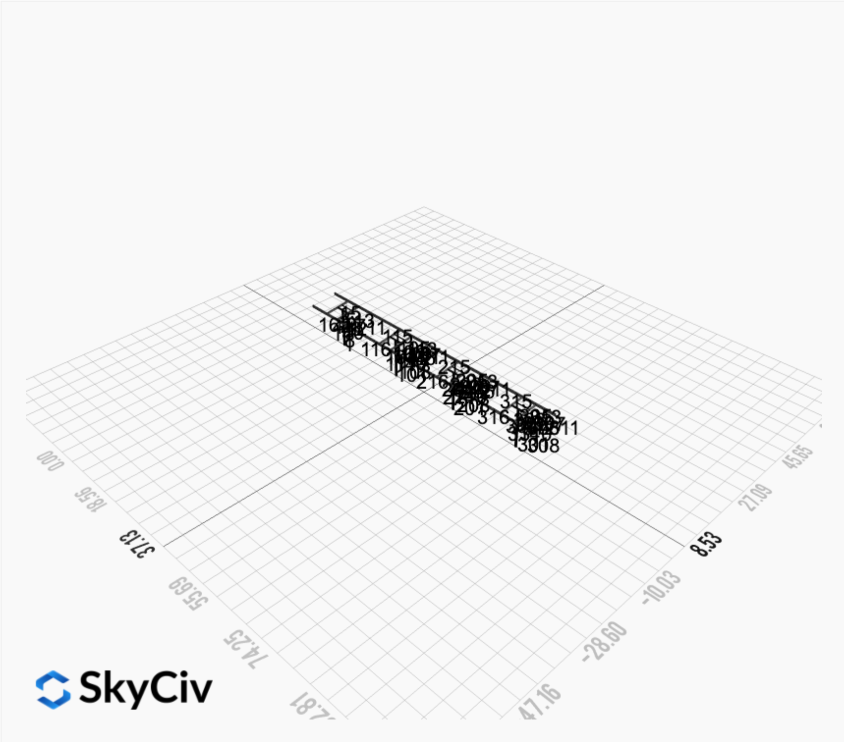
SkyCiv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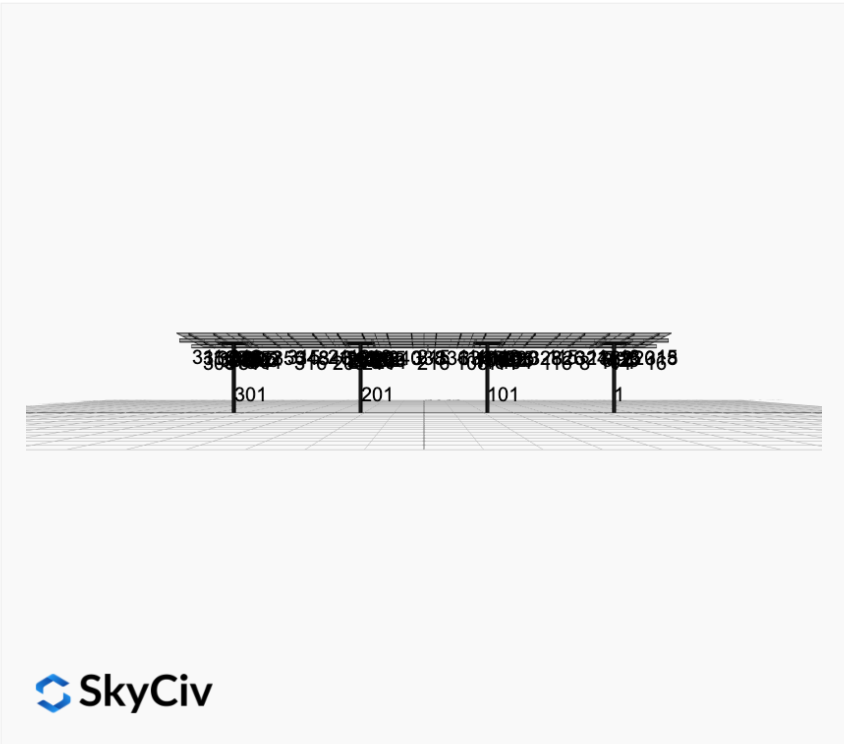
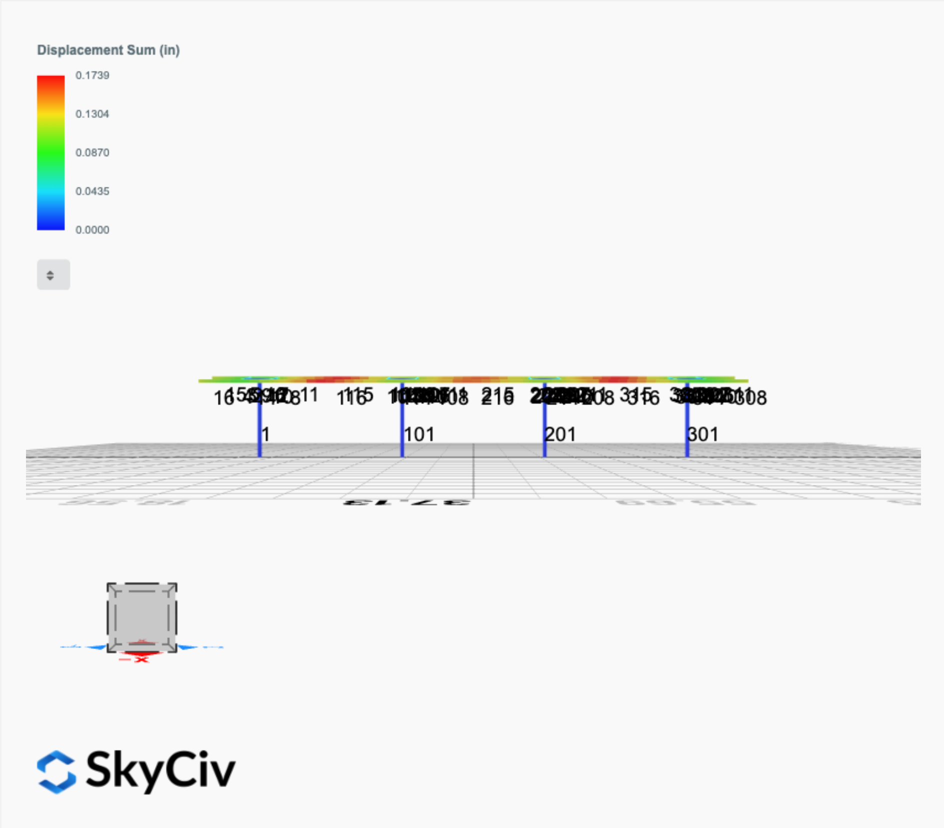
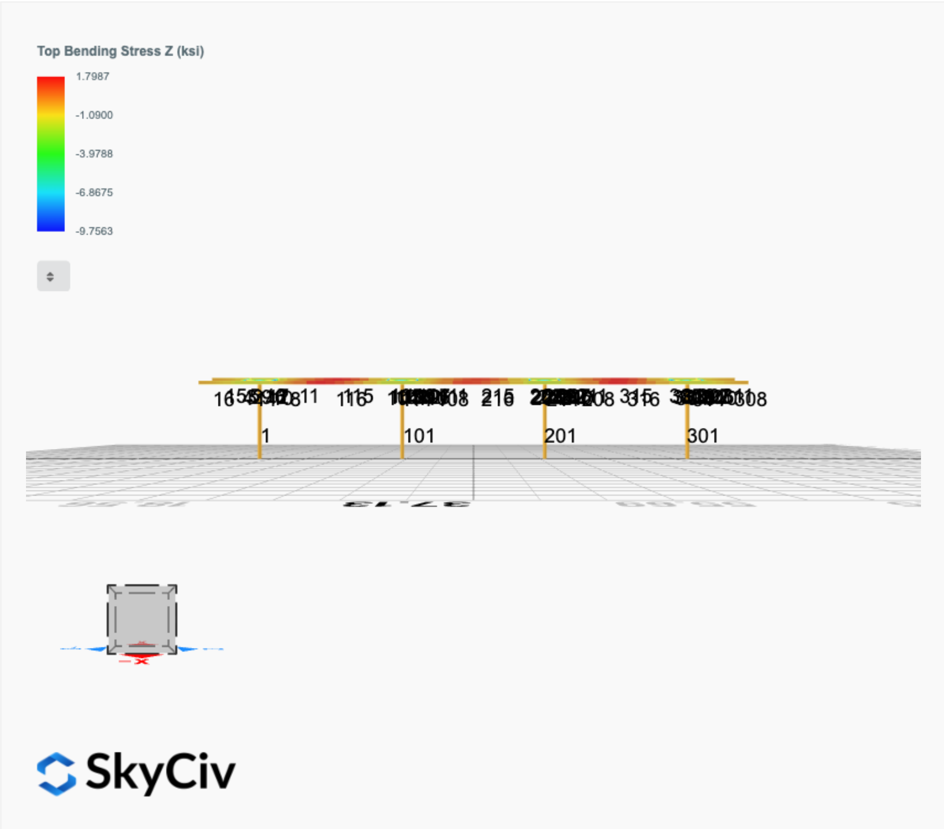
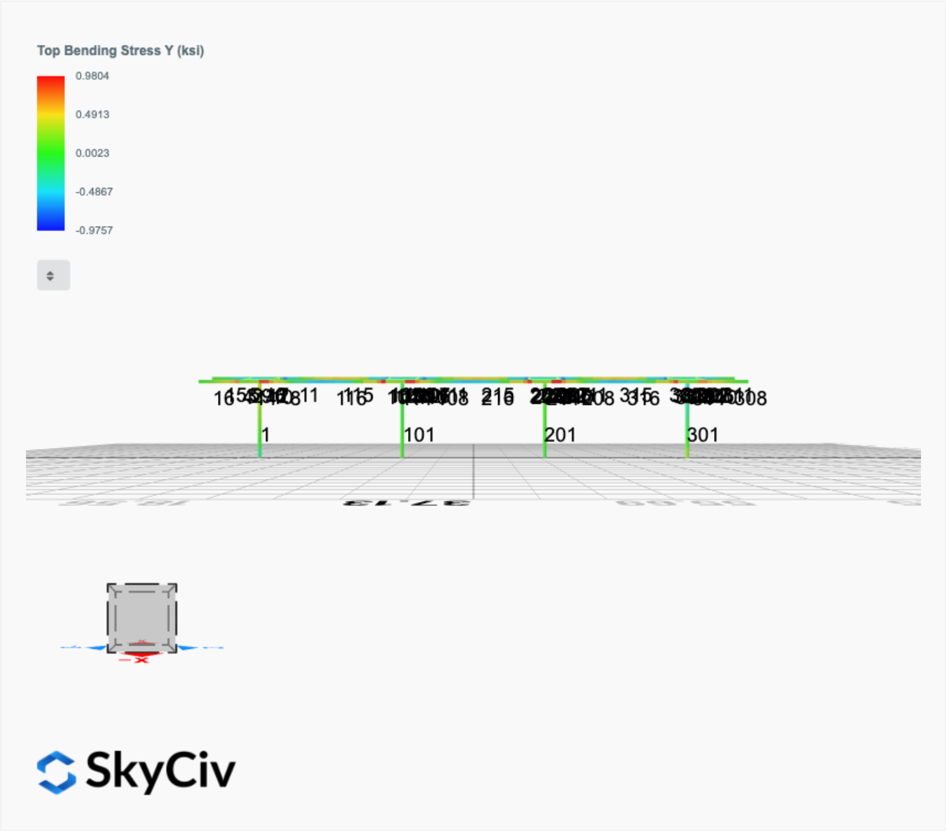
37.13
55.69
74.25
8.53
-10.03
-28.60
47.16
27.09
45.65
SkyCiv

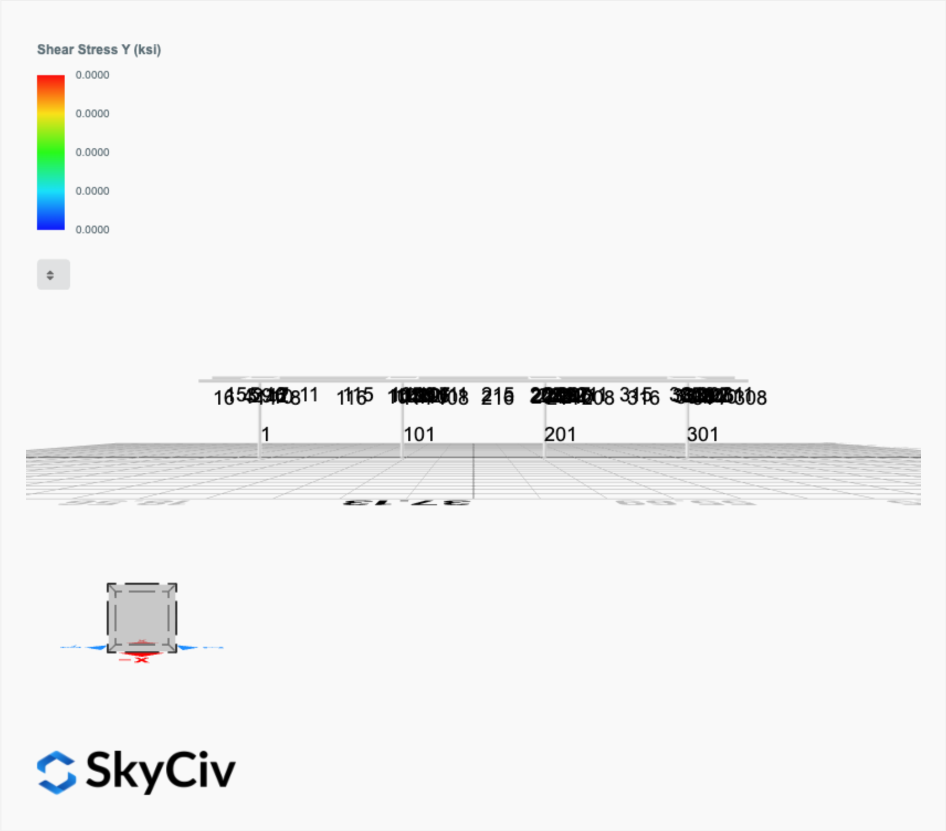

301
201
101
1
SkyCiv

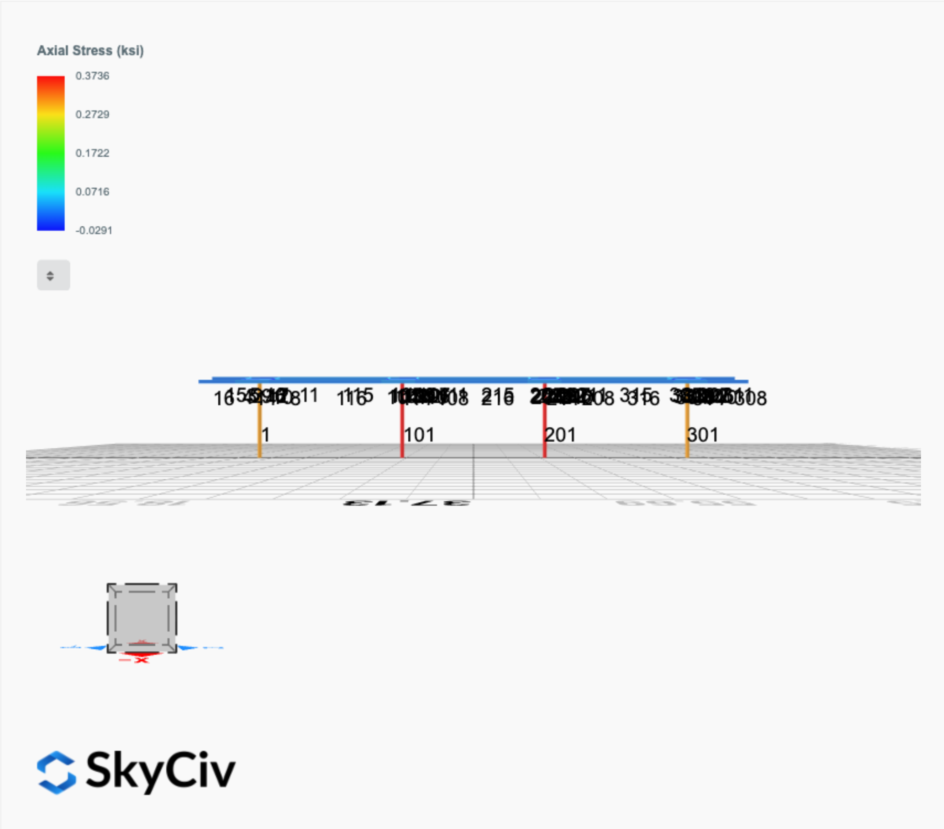
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
0.9804
0.4913
0.0023
-0.4867
-0.9757
1
101
201
301
SkyCiv


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


Axial Stress (ksi)
0.3736
0.2729
0.1722
0.0716
-0.0291
1
101
201
301
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	0.0014	1.9818	0.0321	0.1062	-0.0035	0.0077
ULS: 2. D + L	0.0014	1.9818	0.0321	0.1062	-0.0035	0.0077
ULS: 3. D + (S or Lr or R)	0.0029	3.7737	0.0675	0.2236	-0.0073	-0.0064
ULS: 3. D + (S or Lr or R)	0.0014	1.9818	0.0321	0.1062	-0.0035	0.0077
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0025	3.3257	0.0587	0.1943	-0.0063	-0.0029
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0014	1.9818	0.0321	0.1062	-0.0035	0.0077
ULS: 5b. D + 0.7E	0.0014	1.9818	0.0321	0.1062	-0.0035	0.0077
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0025	3.3257	0.0587	0.1943	-0.0063	-0.0029
ULS: 8. 0.6D + 0.7E	0.0008	1.1891	0.0193	0.0637	-0.0021	0.0046
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2089	4.3288	0.0793	0.2617	-0.0198	2.7893
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2089	4.3288	0.0793	0.2617	-0.0198	2.7893
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0524	1.3488	0.0205	0.0678	-0.0029	1.8558
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1458	0.4909	0.0003	0.0025	0.0141	-6.8042
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1552	5.0860	0.0940	0.3109	-0.0186	2.0833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1552	5.0860	0.0940	0.3109	-0.0186	2.0833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0408	2.8510	0.0500	0.1655	-0.0059	1.3832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1109	2.2076	0.0348	0.1165	0.0068	-5.1118
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1563	3.7421	0.0675	0.2228	-0.0157	2.0939
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1563	3.7421	0.0675	0.2228	-0.0157	2.0939
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0396	1.5071	0.0234	0.0774	-0.0030	1.3938
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1097	0.8636	0.0082	0.0284	0.0097	-5.1012
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2095	3.5361	0.0664	0.2192	-0.0184	2.7862
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2095	3.5361	0.0664	0.2192	-0.0184	2.7862
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0518	0.5561	0.0077	0.0253	-0.0015	1.8527
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1453	-0.3018	-0.0125	-0.0400	0.0155	-6.8072

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	7.2010
Shear X	-0.3505
Shear Z	0.1353
Moment X	0.4477
Moment Y (Twist)	0.0337
Moment Z	11.7222

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.0860
Shear X	-0.2095
Shear Z	0.0940
Moment X	0.3109
Moment Y (Twist)	0.0198
Moment Z	6.8072

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	-0.0014	2.2482	-0.0046	-0.0155	0.0011	0.0353
ULS: 2. D + L	-0.0014	2.2482	-0.0046	-0.0155	0.0011	0.0353
ULS: 3. D + (S or Lr or R)	-0.0029	4.3334	-0.0098	-0.0327	0.0023	0.0519
ULS: 3. D + (S or Lr or R)	-0.0014	2.2482	-0.0046	-0.0155	0.0011	0.0353
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0025	3.8121	-0.0085	-0.0284	0.0020	0.0477
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0014	2.2482	-0.0046	-0.0155	0.0011	0.0353
ULS: 5b. D + 0.7E	-0.0014	2.2482	-0.0046	-0.0155	0.0011	0.0353

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0025	3.8121	-0.0085	-0.0284	0.0020	0.0477
ULS: 8. 0.6D + 0.7E	-0.0008	1.3489	-0.0028	-0.0093	0.0006	0.0212
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2354	4.9795	-0.0111	-0.0372	-0.0001	3.1267
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2354	4.9795	-0.0111	-0.0372	-0.0001	3.1267
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0675	1.5108	-0.0023	-0.0081	-0.0021	2.0064
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1363	0.5147	-0.0016	-0.0045	0.0084	-7.3530
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1780	5.8606	-0.0133	-0.0447	0.0011	2.3663
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1780	5.8606	-0.0133	-0.0447	0.0011	2.3663
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0492	3.2590	-0.0068	-0.0228	-0.0004	1.5261
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1007	2.5120	-0.0062	-0.0201	0.0075	-5.4935
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1769	4.2967	-0.0095	-0.0318	0.0002	2.3539
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1769	4.2967	-0.0095	-0.0318	0.0002	2.3539
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0503	1.6952	-0.0029	-0.0100	-0.0013	1.5136
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1019	0.9481	-0.0023	-0.0072	0.0066	-5.5059
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2348	4.0803	-0.0092	-0.0310	-0.0005	3.1126
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2348	4.0803	-0.0092	-0.0310	-0.0005	3.1126
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0681	0.6115	-0.0005	-0.0019	-0.0026	1.9923
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1368	-0.3846	0.0003	0.0017	0.0080	-7.3672

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	8.3103
Shear X	-0.3920
Shear Z	-0.0192
Moment X	-0.0647
Moment Y (Twist)	0.0149
Moment Z	12.6925

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.8606
Shear X	-0.2354
Shear Z	-0.0133
Moment X	-0.0447
Moment Y (Twist)	0.0084
Moment Z	7.3672

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	-0.0014	2.2482	0.0046	0.0155	-0.0011	0.0353
ULS: 2. D + L	-0.0014	2.2482	0.0046	0.0155	-0.0011	0.0353
ULS: 3. D + (S or Lr or R)	-0.0029	4.3334	0.0098	0.0327	-0.0023	0.0519
ULS: 3. D + (S or Lr or R)	-0.0014	2.2482	0.0046	0.0155	-0.0011	0.0353
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0025	3.8121	0.0085	0.0284	-0.0020	0.0477
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0014	2.2482	0.0046	0.0155	-0.0011	0.0353
ULS: 5b. D + 0.7E	-0.0014	2.2482	0.0046	0.0155	-0.0011	0.0353
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0025	3.8121	0.0085	0.0284	-0.0020	0.0477
ULS: 8. 0.6D + 0.7E	-0.0008	1.3489	0.0028	0.0093	-0.0006	0.0212
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2354	4.9795	0.0111	0.0372	0.0001	3.1267
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2354	4.9795	0.0111	0.0372	0.0001	3.1267
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0675	1.5108	0.0023	0.0081	0.0021	2.0064
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1363	0.5147	0.0016	0.0045	-0.0084	-7.3530
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1780	5.8606	0.0133	0.0447	-0.0011	2.3663
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1780	5.8606	0.0133	0.0447	-0.0011	2.3663
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0492	3.2590	0.0068	0.0228	0.0004	1.5261
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1007	2.5120	0.0062	0.0201	-0.0075	-5.4935

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	-0.1769	4.2967	0.0095	0.0318	-0.0002	2.3539
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1769	4.2967	0.0095	0.0318	-0.0002	2.3539
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0503	1.6952	0.0029	0.0100	0.0013	1.5136
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1019	0.9481	0.0023	0.0072	-0.0066	-5.5059
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2348	4.0803	0.0092	0.0310	0.0005	3.1126
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2348	4.0803	0.0092	0.0310	0.0005	3.1126
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0681	0.6115	0.0005	0.0019	0.0026	1.9923
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1368	-0.3846	-0.0003	-0.0017	-0.0080	-7.3672

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	8.3103
Shear X	-0.3920
Shear Z	0.0192
Moment X	0.0647
Moment Y (Twist)	0.0148
Moment Z	12.6925

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.8606
Shear X	-0.2354
Shear Z	0.0133
Moment X	0.0447
Moment Y (Twist)	0.0084
Moment Z	7.3672

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	0.0014	1.9818	-0.0321	-0.1062	0.0035	0.0077
ULS: 2. D + L	0.0014	1.9818	-0.0321	-0.1062	0.0035	0.0077
ULS: 3. D + (S or Lr or R)	0.0029	3.7737	-0.0675	-0.2236	0.0073	-0.0064
ULS: 3. D + (S or Lr or R)	0.0014	1.9818	-0.0321	-0.1062	0.0035	0.0077
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0025	3.3257	-0.0587	-0.1943	0.0063	-0.0029
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0014	1.9818	-0.0321	-0.1062	0.0035	0.0077
ULS: 5b. D + 0.7E	0.0014	1.9818	-0.0321	-0.1062	0.0035	0.0077
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0025	3.3257	-0.0587	-0.1943	0.0063	-0.0029
ULS: 8. 0.6D + 0.7E	0.0008	1.1891	-0.0193	-0.0637	0.0021	0.0046
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2089	4.3288	-0.0793	-0.2617	0.0198	2.7893
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2089	4.3288	-0.0793	-0.2617	0.0198	2.7893
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0524	1.3488	-0.0205	-0.0678	0.0029	1.8558
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1458	0.4909	-0.0003	-0.0025	-0.0141	-6.8042
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1552	5.0860	-0.0940	-0.3109	0.0186	2.0833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1552	5.0860	-0.0940	-0.3109	0.0186	2.0833
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0408	2.8510	-0.0500	-0.1655	0.0059	1.3832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1109	2.2076	-0.0348	-0.1165	-0.0068	-5.1118
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1563	3.7421	-0.0675	-0.2228	0.0157	2.0939
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1563	3.7421	-0.0675	-0.2228	0.0157	2.0939
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0396	1.5071	-0.0234	-0.0774	0.0030	1.3938
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1097	0.8636	-0.0082	-0.0284	-0.0097	-5.1012
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2095	3.5361	-0.0664	-0.2192	0.0184	2.7862
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2095	3.5361	-0.0664	-0.2192	0.0184	2.7862
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0518	0.5561	-0.0077	-0.0253	0.0015	1.8527
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1453	-0.3018	0.0125	0.0400	-0.0155	-6.8072

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	7.2010
Shear X	-0.3505
Shear Z	-0.1353
Moment X	-0.4477
Moment Y (Twist)	0.0337
Moment Z	11.7222

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

Result	Value (kip, kip-ft)
Axial	5.0860
Shear X	-0.2095
Shear Z	-0.0940
Moment X	-0.3109
Moment Y (Twist)	0.0198
Moment Z	6.8072

Project Details

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

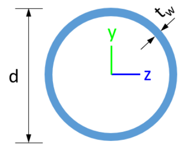
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

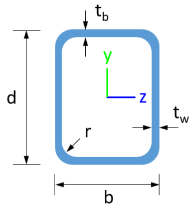
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

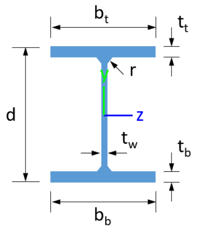
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
7	6in Pipe Sch 40	6.63	0.28					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	22.59	22.59	10.76	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.18,1.18,1.18,1.17	300	200	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.49,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.63,1.68	300	200	1
5	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.67,1.67,1.67,1.66	300	200	1
6	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66	300	200	1
8	18	1.33	1.33	2.05	1.73,1.73,1.73,1.73,1.73,1.73,1.72,1.72,1.48,2.05,1.72,1.72,1.87,2.07,1.73,1.73,1.70,1.81,1.72,1.72,1.61,1.94,1.72,1.72,2.08,2.10	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.50,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
11	18	1.33	1.33	2.05	1.75,1.75,1.75,1.75,1.75,1.75,1.77,1.77,1.87,2.08,1.77,1.77,1.93,2.06,1.76,1.76,1.79,1.62,1.77,1.77,1.83,2.36,1.78,1.78,2.01,2.03	300	200	1
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.17,1.11,1.11,1.12,1.12,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.45,1.11,1.11,1.12,1.12	300	200	1
14	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.07,1.13,1.11,1.11,2.77,1.17,1.11,1.11,1.10,1.11,1.11,1.11,1.09,1.12,1.11,1.11,1.26,1.27	300	200	1
15	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	7	22.59	22.59	10.76	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.47,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.67,1.67,1.67,1.66	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.18	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66	300	200	1

108	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.10,2.24,2.07,2.10,2.10,1.66,2.07,2.10,2.10,2.10,2.09,2.10,2.10,2.11,2.08,2.10,2.10,2.07,2.06	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.67,1.67,1.67,1.51,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
111	18	1.33	1.33	2.05	2.09,2.09,2.09,2.10,2.09,2.09,2.09,2.09,2.09,2.06,2.09,2.09,2.08,2.07,2.09,2.09,2.09,2.11,2.09,2.09,2.09,1.83,2.09,2.09,2.08,2.07	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.19,1.04,1.04,1.06,1.12,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.66,1.04,1.04,1.09,1.09	300	200	1
114	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.10,1.04,1.04,1.68,1.19,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.06,1.04,1.04,1.29,1.31	300	200	1
115	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.13,1.16,1.16,1.15,1.14,1.16,1.16,1.16,1.17,1.16,1.16,1.15,1.11,1.16,1.16,1.14,1.14	300	200	1
116	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.18,1.14,1.16,1.16,1.12,1.13,1.16,1.16,1.16,1.15,1.16,1.16,1.17,1.14,1.16,1.16,1.13,1.12	300	200	1
201	7	22.59	22.59	10.76	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.67,1.67,1.67,1.51,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.67,1.67,1.67,1.66	300	200	1
208	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.15,2.01,2.08,2.08,1.34,1.88,2.08,2.08,2.09,2.07,2.08,2.08,2.10,2.06,2.08,2.08,1.88,1.76	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.69,1.68,1.67,1.67,1.47,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
211	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.07,1.85,2.08,2.08,2.06,1.98,2.08,2.08,2.08,2.11,2.08,2.08,2.07,1.55,2.08,2.08,2.06,2.03	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.19,1.04,1.04,1.06,1.12,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.66,1.04,1.04,1.09,1.09	300	200	1
214	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.10,1.04,1.04,1.68,1.19,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.06,1.04,1.04,1.29,1.31	300	200	1
215	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.13,1.16,1.16,1.15,1.15	300	200	1
216	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.15,1.16,1.16,1.12,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.15,1.14	300	200	1
301	7	22.59	22.59	10.76	-	300	200	1

302	4	1.30	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	300	200	1
304	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.50,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.68	300	200	1
305	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66	300	200	1
306	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.18,1.18,1.18,1.17	300	200	1
307	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.67,1.67,1.67,1.66	300	200	1
308	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.49,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.63,1.68	300	200	1
311	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.17,1.11,1.11,1.12,1.12,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.45,1.11,1.11,1.12,1.12	300	200	1
314	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.07,1.13,1.11,1.11,2.77,1.17,1.11,1.11,1.10,1.11,1.11,1.11,1.09,1.12,1.11,1.11,1.26,1.27	300	200	1
315	18	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.15,1.13,1.13,1.14,1.14,1.12,1.12,1.13,1.11,1.12,1.12,1.13,1.19,1.13,1.13,1.14,1.14	300	200	1
316	18	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.10,1.14,1.12,1.12,1.31,1.15,1.12,1.12,1.12,1.13,1.12,1.12,1.11,1.14,1.12,1.12,1.16,1.16	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	86.55	42.30	42.30	75.35	75.35
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	19.37	6.45	30.09	45.74
14	120.60	98.23	18.84	6.45	30.09	45.74
15	120.60	54.44	23.36	6.45	30.09	45.74
16	120.60	54.44	23.36	6.45	30.09	45.74
101	251.16	86.55	42.30	42.30	75.35	75.35
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61

103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	18.13	6.45	30.09	45.74
114	120.60	98.23	18.13	6.45	30.09	45.74
115	120.60	68.63	15.16	6.45	30.09	45.74
116	120.60	68.63	15.30	6.45	30.09	45.74
201	251.16	86.55	42.30	42.30	75.35	75.35
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61
208	120.60	117.88	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	117.88	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	18.13	6.45	30.09	45.74
214	120.60	98.23	18.13	6.45	30.09	45.74
215	120.60	68.63	15.44	6.45	30.09	45.74
216	120.60	68.63	15.30	6.45	30.09	45.74
301	251.16	86.55	42.30	42.30	75.35	75.35
302	142.83	141.72	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	4.60	29.14	16.61
304	79.65	72.01	10.99	4.60	29.14	16.61
305	79.65	73.44	10.99	4.60	29.14	16.61
306	79.65	74.02	10.99	4.60	29.14	16.61
307	79.65	73.44	10.99	4.60	29.14	16.61
308	120.60	54.44	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	4.60	29.14	16.61
311	120.60	54.44	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	98.23	19.37	6.45	30.09	45.74
314	120.60	98.23	18.84	6.45	30.09	45.74
315	120.60	68.63	15.16	6.45	30.09	45.74
316	120.60	68.63	15.03	6.45	30.09	45.74

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	0.083	0.277	0.024	0.005	0.002	0.282	#16	0.604	Not Required	Pass
2	0.001	0.356	0.023	0.076	0.004	0.378	#13	0.034	Not Required	Pass
3	0.002	0.567	0.007	0.057	0.001	0.572	#13	0.044	Not Required	Pass
4	0.001	0.543	0.028	0.055	0.005	0.578	#21	0.078	Not Required	Pass

4	0.001	0.543	0.038	0.055	0.005	0.578	#21	0.078	Not Required	Pass
5	0.002	0.351	0.024	0.057	0.003	0.355	#13	0.073	Not Required	Pass
6	0.002	0.634	0.031	0.065	0.004	0.657	#13	0.044	Not Required	Pass
7	0.002	0.392	0.051	0.064	0.008	0.403	#13	0.073	Not Required	Pass
8	0.001	0.072	0.019	0.038	0.002	0.081	#21	0.088	Not Required	Pass
9	0.002	0.075	0.015	0.002	0.001	0.091	#21	0.198	Not Required	Pass
10	0.002	0.604	0.039	0.061	0.005	0.613	#21	0.078	Not Required	Pass
11	0.001	0.073	0.020	0.040	0.002	0.080	#21	0.088	Not Required	Pass
12	0.000	0.418	0.025	0.086	0.004	0.443	#13	0.052	Not Required	Pass
13	0.001	0.172	0.045	0.052	0.002	0.184	#21	0.265	Not Required	Pass
14	0.001	0.167	0.044	0.049	0.002	0.179	#21	0.177	Not Required	Pass
15	0.000	0.061	0.013	0.025	0.001	0.074	#21	Not Required	Not Required	Pass
16	0.000	0.059	0.013	0.024	0.001	0.072	#21	Not Required	Not Required	Pass
101	0.096	0.300	0.003	0.005	0.000	0.305	#16	0.604	Not Required	Pass
102	0.000	0.454	0.028	0.095	0.004	0.481	#13	0.052	Not Required	Pass
103	0.002	0.699	0.019	0.071	0.002	0.713	#13	0.044	Not Required	Pass
104	0.002	0.672	0.039	0.068	0.005	0.698	#21	0.078	Not Required	Pass
105	0.002	0.433	0.043	0.070	0.006	0.441	#13	0.073	Not Required	Pass
106	0.002	0.692	0.018	0.070	0.003	0.699	#13	0.044	Not Required	Pass
107	0.002	0.429	0.038	0.070	0.005	0.434	#13	0.073	Not Required	Pass
108	0.001	0.049	0.014	0.040	0.002	0.055	#21	0.088	Not Required	Pass
109	0.002	0.077	0.010	0.001	0.000	0.087	#21	0.198	Not Required	Pass
110	0.002	0.663	0.039	0.067	0.005	0.691	#21	0.078	Not Required	Pass
111	0.001	0.052	0.014	0.041	0.002	0.057	#21	0.088	Not Required	Pass
112	0.000	0.445	0.028	0.093	0.005	0.472	#13	0.052	Not Required	Pass
113	0.001	0.198	0.041	0.054	0.002	0.223	#21	0.265	Not Required	Pass
114	0.001	0.197	0.041	0.052	0.002	0.220	#21	0.265	Not Required	Pass
115	0.001	0.204	0.021	0.043	0.002	0.223	#21	0.439	Not Required	Pass
116	0.001	0.197	0.022	0.041	0.002	0.219	#21	0.439	Not Required	Pass
201	0.096	0.300	0.003	0.005	0.000	0.305	#16	0.604	Not Required	Pass
202	0.000	0.445	0.028	0.093	0.005	0.472	#13	0.052	Not Required	Pass
203	0.002	0.692	0.018	0.070	0.003	0.699	#13	0.044	Not Required	Pass
204	0.002	0.663	0.039	0.067	0.005	0.691	#21	0.078	Not Required	Pass
205	0.002	0.429	0.038	0.070	0.005	0.434	#13	0.073	Not Required	Pass
206	0.002	0.699	0.019	0.071	0.002	0.713	#13	0.044	Not Required	Pass
207	0.002	0.433	0.043	0.070	0.006	0.441	#13	0.073	Not Required	Pass
208	0.001	0.056	0.017	0.041	0.002	0.061	#21	0.088	Not Required	Pass
209	0.002	0.077	0.010	0.001	0.000	0.087	#21	0.198	Not Required	Pass
210	0.002	0.672	0.039	0.068	0.005	0.698	#21	0.078	Not Required	Pass
211	0.001	0.059	0.017	0.043	0.002	0.063	#21	0.088	Not Required	Pass
212	0.000	0.454	0.028	0.095	0.004	0.481	#13	0.052	Not Required	Pass
213	0.001	0.198	0.041	0.054	0.002	0.223	#21	0.265	Not Required	Pass
214	0.001	0.197	0.041	0.052	0.002	0.220	#21	0.265	Not Required	Pass
215	0.001	0.182	0.022	0.041	0.002	0.201	#21	0.439	Not Required	Pass
216	0.001	0.173	0.022	0.040	0.002	0.196	#21	0.439	Not Required	Pass
301	0.083	0.277	0.024	0.005	0.002	0.282	#16	0.604	Not Required	Pass
302	0.000	0.418	0.025	0.086	0.004	0.443	#13	0.052	Not Required	Pass
303	0.002	0.634	0.031	0.065	0.004	0.657	#13	0.044	Not Required	Pass
304	0.002	0.604	0.039	0.061	0.005	0.613	#21	0.078	Not Required	Pass
305	0.002	0.392	0.051	0.064	0.008	0.403	#13	0.073	Not Required	Pass
306	0.002	0.567	0.007	0.057	0.001	0.572	#13	0.044	Not Required	Pass
307	0.002	0.351	0.024	0.057	0.003	0.355	#13	0.073	Not Required	Pass
308	0.000	0.059	0.013	0.024	0.001	0.072	#21	Not Required	Not Required	Pass
309	0.002	0.075	0.015	0.002	0.001	0.091	#21	0.198	Not Required	Pass

310	0.001	0.543	0.038	0.055	0.005	0.578	#21	0.078	Not Required	Pass
311	0.000	0.061	0.013	0.025	0.001	0.074	#21	Not Required	Not Required	Pass
312	0.001	0.356	0.023	0.076	0.004	0.378	#13	0.034	Not Required	Pass
313	0.001	0.172	0.045	0.052	0.002	0.184	#21	0.177	Not Required	Pass
314	0.001	0.167	0.044	0.049	0.002	0.179	#21	0.265	Not Required	Pass
315	0.001	0.210	0.022	0.040	0.002	0.229	#21	0.439	Not Required	Pass
316	0.001	0.202	0.022	0.038	0.002	0.225	#21	0.439	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

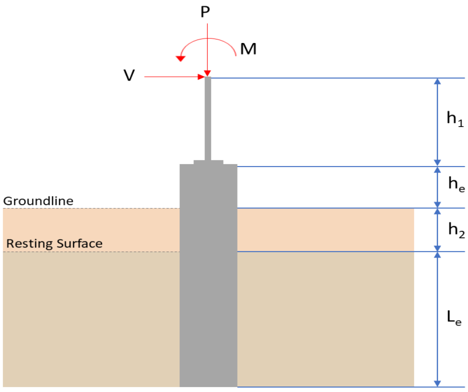
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 6.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.086	7.201
V_x (kip)	-0.209	-0.351
V_z (kip)	0.094	0.135
M_x (kipft)	0.311	0.448
M_z (kipft)	6.807	11.722

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.209\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.069667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.807 \text{ kipft}) + ((-0.209 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.269 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2496 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.094 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.031333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.311 \text{ kipft}) + ((0.094 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.10367 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.7677 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.2496 \text{ ft}), (2.7677 \text{ ft})]$$

$$L_{e,req} = 6.25 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.25 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.96154$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(5.086 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.71952\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.71952\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.35976$$

Status: **PASS**
Ratio: **0.360**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.069667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.269\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.269\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.069667\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (2.269\ \mathrm{kipft/ft})) + (4 \times (-0.069667\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.3969\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.269\ \mathrm{kipft/ft})) + (3 \times (-0.069667\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (2.269\ \mathrm{kipft/ft})) + (2 \times (-0.069667\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.2814\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.269\ \mathrm{kipft/ft})) + ((-0.069667\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.91131\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.3969\ \mathrm{ft})}{2}$$

$$p_a = 0.32977\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2814\ \mathrm{kip/ft^2}\right)}{\left(0.32977\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85332$$

Status: **PASS**
Ratio: **0.850**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.91131\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93467$$

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

Considering z-direction:

$H_o = 0.031333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10367\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10367\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.031333\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.10367\ \mathrm{kipft/ft})) + (4 \times (0.031333\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6405\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.10367\ \mathrm{kipft/ft})) + (3 \times (0.031333\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.10367\ \mathrm{kipft/ft})) + (2 \times (0.031333\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.040832\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.10367\ \mathrm{kipft/ft})) + ((0.031333\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.091685\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6405\ \mathrm{ft})}{2}$$

$$p_a = 0.34804\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.040832\ \mathrm{kip/ft^2}\right)}{\left(0.34804\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.11732$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

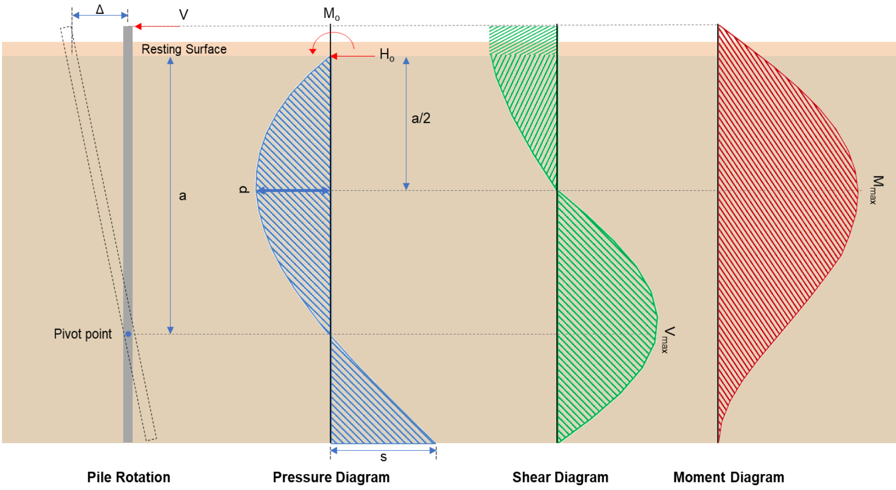
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.091685\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.094036$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{\left(-0.351\ \mathrm{kip}\right)}{\left(36\ \mathrm{in}\right)}$$

$$H_o = -0.117\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{\left(11.722\ \mathrm{kipft}\right) + \left(\left(-0.351\ \mathrm{kip}\right) \times \left(0\ \mathrm{ft}\right)\right)}{\left(36\ \mathrm{in}\right)}$$

$$M_o = 3.9073\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{\left(3.9073\ \mathrm{kipft/ft}\right)}{\left(-0.117\ \mathrm{kip/ft}\right)}$$

$$E = 33.396\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(3.9073\ \mathrm{kipft/ft}\right) \times \left(6.5\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.117\ \mathrm{kip/ft}\right) \times \left(6.5\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(3.9073\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.117\ \mathrm{kip/ft}\right) \times \left(6.5\ \mathrm{ft}\right)\right)}$$

$$a = 4.3955\ \mathrm{ft}$$

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

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

$$V_{max} = \left(\left(-0.117\ \mathrm{kip/ft}\right) \times \left(36\ \mathrm{in}\right)\right) \times \left[1 - \left[3 \times \left(\frac{4 \times \left(33.396\ \mathrm{ft}\right)}{\left(6.5\ \mathrm{ft}\right)} + 3\right) \times \left(\frac{\left(4.3955\ \mathrm{ft}\right)}{\left(6.5\ \mathrm{ft}\right)}\right)^2\right] + \left[4 \times \left(\frac{3 \times \left(33.396\ \mathrm{ft}\right)}{\left(6.5\ \mathrm{ft}\right)} + 2\right) \times \left(\frac{\left(4.3955\ \mathrm{ft}\right)}{\left(6.5\ \mathrm{ft}\right)}\right)^3\right]\right]$$

$$V_{max} = 3.4293 \text{ kip}$$

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

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

$$M_{max} = ((-0.117 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(33.396 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (33.396 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (33.396 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 10.936 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.135 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.045 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.448 \text{ kipft}) + ((0.135 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.14933 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.14933 \text{ kipft/ft})}{(0.045 \text{ kip/ft})}$$

$$E = 3.3185 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14933 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.045 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.14933 \text{ kipft/ft})) + (4 \times (0.045 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6401 \text{ ft}$$

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

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

$$V_{max} = ((0.045 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6401 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6401 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21188 \text{ kip}$$

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

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

$$M_{max} = ((0.045 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.3185 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.61031 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.201 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.148 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.148 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.201\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.0057428$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \mathrm{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \mathrm{in})$$

$$d = 28.8\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 186.09\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 7.201\ \mathrm{kip} \rightarrow 7201\ \mathrm{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(7201\ \mathrm{lbf})}{6 \times (1017.9\ \mathrm{in}^2)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 75.66\ \mathrm{kip}$$

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 204.04\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (75.66\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 75.66\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.66\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.99\ \text{kip}$$

Considering x-direction:

$V_{max} = 3.4293\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.4293\ \text{kip})}{(73.99\ \text{kip})}$$

$$Ratio = 0.046348$$

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

Considering z-direction:

$V_{max} = 0.21188\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21188\ \text{kip})}{(73.99\ \text{kip})}$$

$$Ratio = 0.0028636$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

$$S_m = 4580.4\ \text{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 62.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$

$$\phi M_n = 62.027\ \text{kipft}$$

Considering x-direction:

$M_{max} = 10.936\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.936\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.1763$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$M_{max} = 0.61031\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.61031\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.0098395$$

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

REFERENCES	CALCULATIONS	RESULTS

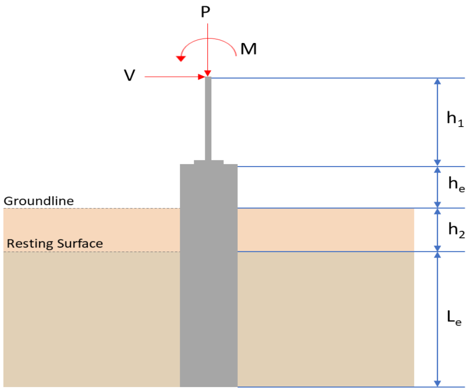
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 6.5 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.086	7.201
V_x (kip)	-0.209	-0.351
V_z (kip)	-0.094	-0.135
M_x (kipft)	-0.311	-0.448
M_z (kipft)	6.807	11.722

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.209 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.069667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.807\ \text{kipft}) + ((-0.209\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 2.269\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2496\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.094\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.031333\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.311\ \text{kipft}) + ((-0.094\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.10367\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.9398\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.2496\ \text{ft}), (1.9398\ \text{ft})]$$

$$L_{e,req} = 6.25\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.25\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.96154$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(5.086\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

SkyCiv

$$q = 0.71952 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.71952 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.35976$$

Status: **PASS**
Ratio: **0.360**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.069667 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.269 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.269 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.069667 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (2.269 \text{ kipft/ft})) + (4 \times (-0.069667 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.3969 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.269 \text{ kipft/ft})) + (3 \times (-0.069667 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (2.269 \text{ kipft/ft})) + (2 \times (-0.069667 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.2814 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.269 \text{ kipft/ft})) + ((-0.069667 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.91131 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.3969 \text{ ft})}{2}$$

$$p_a = 0.32977 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.2814 \text{ kip/ft}^2)}{(0.32977 \text{ kip/ft}^2)}$$

$$Ratio = 0.85332$$

Status: **PASS**
Ratio: **0.850**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.91131\ \text{kip/ft}^2\right)}{\left(0.975\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.93467$$

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

Considering z-direction:

$H_o = -0.031333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10367\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10367\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.031333\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.10367\ \text{kipft/ft})) + (4 \times (-0.031333\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6405\ \text{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.10367\ \text{kipft/ft})) + (3 \times (-0.031333\ \text{kip/ft}) \times (6.5\ \text{ft}))]^{\,2}}{(6.5\ \text{ft})^2 \times [(3 \times (0.10367\ \text{kipft/ft})) + (2 \times (-0.031333\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = -0.011157\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.10367\ \text{kipft/ft})) + ((-0.031333\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.00081795\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.6405\ \text{ft})}{2}$$

$$p_a = 0.34804\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.011157\ \text{kip/ft}^2\right)}{\left(0.34804\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.032056$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

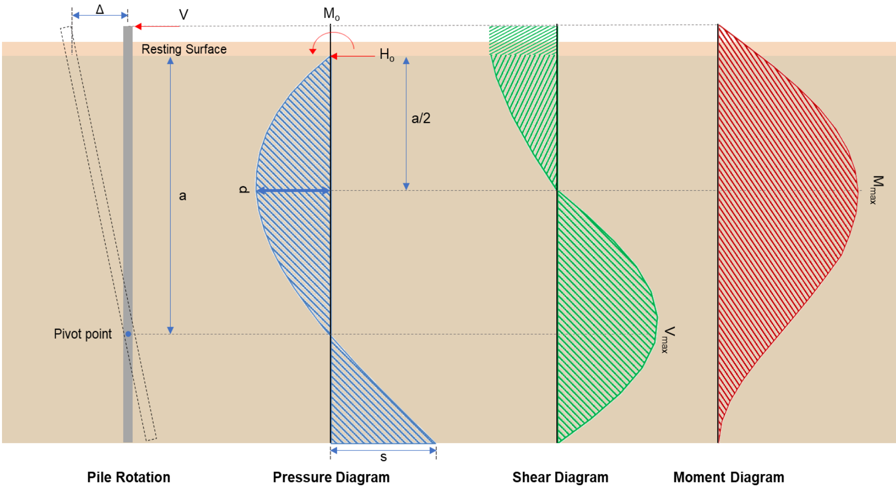
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.00081795\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00083892$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.351\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.117\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.722\ \mathrm{kipft}) + ((-0.351\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 3.9073\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.9073\ \mathrm{kipft/ft})}{(-0.117\ \mathrm{kip/ft})}$$

$$E = 33.396\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.9073\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.117\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (3.9073\ \mathrm{kipft/ft})) + (4 \times (-0.117\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.3955\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.117\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (33.396\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.3955\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (33.396\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.3955\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.4293 \text{ kip}$$

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

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

$$M_{max} = ((-0.117 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(33.396 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (33.396 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (33.396 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.3955 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 10.936 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.135 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.045 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.448 \text{ kipft}) + ((-0.135 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.14933 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.14933 \text{ kipft/ft})}{(-0.045 \text{ kip/ft})}$$

$$E = 3.3185 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14933 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.045 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.14933 \text{ kipft/ft})) + (4 \times (-0.045 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6401 \text{ ft}$$

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

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

$$V_{max} = ((-0.045 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6401 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6401 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21188 \text{ kip}$$

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

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

$$M_{max} = ((-0.045 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.3185 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3185 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6401 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.61031 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.201 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.148 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.148 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.201\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0057428$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 7.201\ \text{kip} \rightarrow 7201\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(7201\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.66\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.66\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.66\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.66\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.99\ \text{kip}$$

Considering x-direction:

$V_{max} = 3.4293\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.4293\ \text{kip})}{(73.99\ \text{kip})}$$

$$Ratio = 0.046348$$

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

Considering z-direction:

$V_{max} = 0.21188\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21188\ \text{kip})}{(73.99\ \text{kip})}$$

$$Ratio = 0.0028636$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\ D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

SkyCiv

	$S_m = 4580.4\ \text{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 10.936\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(10.936\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.1763$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 0.61031\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.61031\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.0098395$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

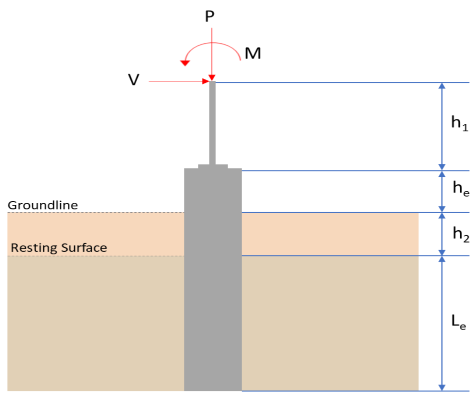
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 6.75\ \mathrm{ft}$ - 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)	5.861	8.310
V_x (kip)	-0.235	-0.392
V_z (kip)	-0.013	-0.019
M_x (kipft)	-0.045	-0.065
M_z (kipft)	7.367	12.692

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,

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

$$H_o = \frac{(-0.235\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.078333\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.367 \text{ kipft}) + ((-0.235 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.4557 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.3938 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.013 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0043333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.045 \text{ kipft}) + ((-0.013 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.015 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.1255 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3938 \text{ ft}), (1.1255 \text{ ft})]$$

$$L_{e,req} = 6.394 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.394 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.94726$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(5.861 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.82916\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.82916\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.41458$$

Status: **PASS**
Ratio: **0.410**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.75\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.078333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.4557\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.4557\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.078333\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (2.4557\ \text{kipft/ft})) + (4 \times (-0.078333\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.5706\ \text{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.4557\ \text{kipft/ft})) + (3 \times (-0.078333\ \text{kip/ft}) \times (6.75\ \text{ft}))]^{\ 2}}{(6.75\ \text{ft})^2 \times [(3 \times (2.4557\ \text{kipft/ft})) + (2 \times (-0.078333\ \text{kip/ft}) \times (6.75\ \text{ft}))]}$$

$$p = 0.27798\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.4557\ \text{kipft/ft})) + ((-0.078333\ \text{kip/ft}) \times (6.75\ \text{ft}))]}{(6.75\ \text{ft})^2}$$

$$s = 0.90658\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.5706\ \text{ft})}{2}$$

$$p_a = 0.3428\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27798\ \text{kip/ft}^2)}{(0.3428\ \text{kip/ft}^2)}$$

$$Ratio = 0.81093$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.90658\ \mathrm{kip/ft^2})}{(1.0125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.89538$$

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = -0.0043333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.015\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.015\ \mathrm{kipft/ft})) + (4 \times (-0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8179\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.015\ \mathrm{kipft/ft})) + (3 \times (-0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.015\ \mathrm{kipft/ft})) + (2 \times (-0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.0014748\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.015\ \mathrm{kipft/ft})) + ((-0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.00015514\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8179\ \mathrm{ft})}{2}$$

$$p_a = 0.36135\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0014748\ \mathrm{kip/ft^2})}{(0.36135\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.0040814$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

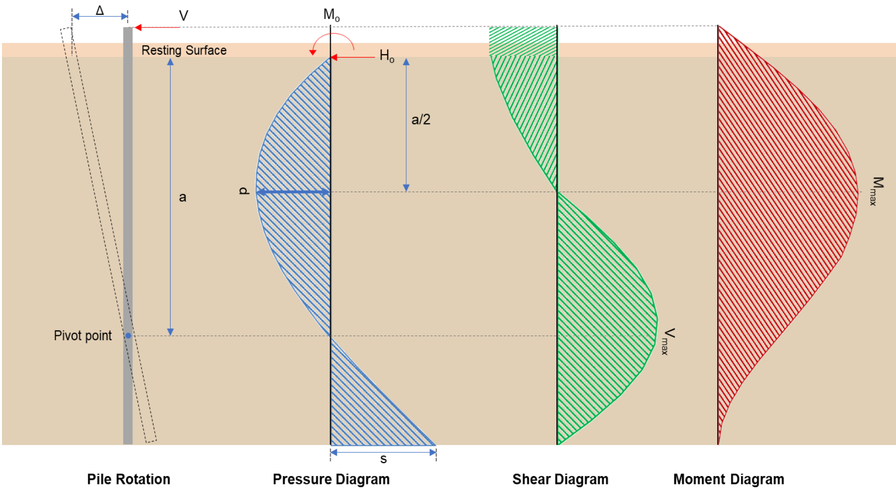
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.00015514\ \text{kip/ft}^2\right)}{\left(1.0125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.00015323$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.392\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.13067\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.692\ \text{kipft}) + ((-0.392\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 4.2307\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2307\ \text{kipft/ft})}{(-0.13067\ \text{kip/ft})}$$

$$E = 32.378\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2307\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.13067\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (4.2307\ \text{kipft/ft})) + (4 \times (-0.13067\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.5686\ \text{ft}$$

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

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

$$V_{max} = ((-0.13067\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (32.378\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.5686\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (32.378\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.5686\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.5922 \text{ kip}$$

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

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

$$M_{max} = ((-0.13067 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(32.378 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (32.378 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (32.378 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 11.881 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.019 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0063333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.065 \text{ kipft}) + ((-0.019 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.021667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.021667 \text{ kipft/ft})}{(-0.0063333 \text{ kip/ft})}$$

$$E = 3.4211 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.021667 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.0063333 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.021667 \text{ kipft/ft})) + (4 \times (-0.0063333 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8196 \text{ ft}$$

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

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

$$V_{max} = ((-0.0063333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.8196 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.8196 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.029696 \text{ kip}$$

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

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

$$M_{max} = ((-0.0063333 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(3.4211 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.088783 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(8.31 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -37.114 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.114 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.31\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0066273$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 8.31\ \text{kip} \rightarrow 8310\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(8310\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.849\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.849\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.849\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.849\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.112\ \text{kip}$$

Considering x-direction:

$V_{max} = 3.5922\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.5922\ \text{kip})}{(74.112\ \text{kip})}$$

$$Ratio = 0.04847$$

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

Considering z-direction:

$V_{max} = 0.029696\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.029696\ \text{kip})}{(74.112\ \text{kip})}$$

$$Ratio = 0.00040069$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$S_m = 4580.4 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi \, 0.85 \, f_{ck}' \, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 11.881 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(11.881 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.19155$$	Status: **PASS** Ratio: **0.190**
	Considering z-direction: $M_{max} = 0.088783 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.088783 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0014314$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

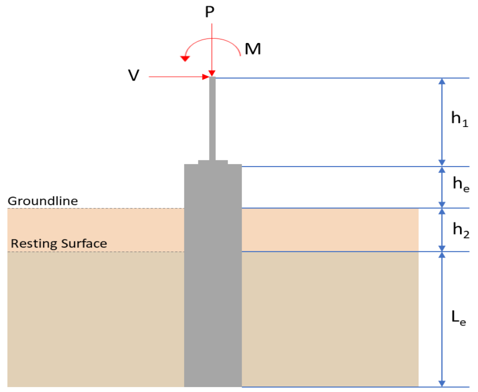
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36$ in - Pile diameter
$L = 6.75$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.861	8.310
V_x (kip)	-0.235	-0.392
V_z (kip)	0.013	0.019
M_x (kipft)	0.045	0.065
M_z (kipft)	7.367	12.692

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,

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

$$H_o = \frac{(-0.235 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.078333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.367 \text{ kipft}) + ((-0.235 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.4557 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.3938 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.013 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0043333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.045 \text{ kipft}) + ((0.013 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.015 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.3452 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3938 \text{ ft}), (1.3452 \text{ ft})]$$

$$L_{e,req} = 6.394 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.394 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.94726$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(5.861 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.82916 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.82916 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.41458$$

Status: **PASS**
Ratio: **0.410**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.25$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.078333 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.4557 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.4557 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.078333 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (2.4557 \text{ kipft/ft})) + (4 \times (-0.078333 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.5706 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.4557 \text{ kipft/ft})) + (3 \times (-0.078333 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\ 2}}{(6.75 \text{ ft})^2 \times [(3 \times (2.4557 \text{ kipft/ft})) + (2 \times (-0.078333 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.27798 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.4557 \text{ kipft/ft})) + ((-0.078333 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.90658 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.5706 \text{ ft})}{2}$$

$$p_a = 0.3428 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27798 \text{ kip/ft}^2\right)}{\left(0.3428 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.81093$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.90658\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89538$$

Status: PASS
Ratio: 0.900

Considering z-direction:

$H_o = 0.0043333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.015\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.015\ \mathrm{kipft/ft})) + (4 \times (0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8179\ \mathrm{ft}$$

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

$$p = \frac{1.178\, \left[(4\, M_o) + (3\, H_o\, L_e)\right]^2}{L_e^2\, \left[(3\, M_o) + (2\, H_o\, L_e)\right]}$$

$$p = \frac{1.178 \times \left[(4 \times (0.015\ \mathrm{kipft/ft})) + (3 \times (0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))\right]^2}{(6.75\ \mathrm{ft})^2 \times \left[(3 \times (0.015\ \mathrm{kipft/ft})) + (2 \times (0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))\right]}$$

$$p = 0.0054532\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, \left[(2\, M_o) + (H_o\, L_e)\right]}{L_e^2}$$

$$s = \frac{9.425 \times \left[(2 \times (0.015\ \mathrm{kipft/ft})) + ((0.0043333\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))\right]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.012256\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8179\ \mathrm{ft})}{2}$$

$$p_a = 0.36135\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0054532\ \mathrm{kip/ft^2}\right)}{\left(0.36135\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.015091$$

Status: PASS
Ratio: 0.020

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

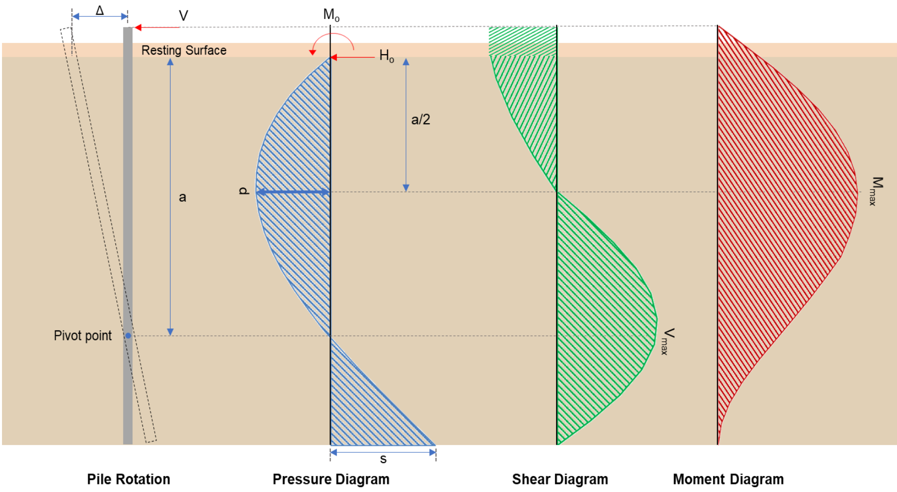
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.012256\ \mathrm{kip/ft^2})}{(1.0125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.012105$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.392\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.13067\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.692\ \mathrm{kipft}) + ((-0.392\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 4.2307\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2307\ \mathrm{kipft/ft})}{(-0.13067\ \mathrm{kip/ft})}$$

$$E = 32.378\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2307\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.13067\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (4.2307\ \mathrm{kipft/ft})) + (4 \times (-0.13067\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.5686\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.13067\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (32.378\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.5686\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (32.378\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.5686\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.5922 \text{ kip}$$

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

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

$$M_{max} = ((-0.13067 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(32.378 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (32.378 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (32.378 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.5686 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 11.881 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.019 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0063333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.065 \text{ kipft}) + ((0.019 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.021667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.021667 \text{ kipft/ft})}{(0.0063333 \text{ kip/ft})}$$

$$E = 3.4211 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.021667 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (0.0063333 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.021667 \text{ kipft/ft})) + (4 \times (0.0063333 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8196 \text{ ft}$$

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

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

$$V_{max} = ((0.0063333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8196 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8196 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.029696 \text{ kip}$$

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

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

$$M_{max} = ((0.0063333 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(3.4211 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4211 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8196 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.088783 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.31 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.114 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.114 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.31\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0066273$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 8.31\ \text{kip} \rightarrow 8310\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(8310\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.849\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.849\ \text{kip}), (204.04\ \text{kip})\right]$$

	$V_c = 75.849 \text{ kip}$	
	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) $$V_{s,a} = 8 \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$ $$V_{s,a} = 414.72 \text{ kip}$$ 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) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$ $$V_{s,b} = 38.17 \text{ kip}$$ V_s - Governing shear strength of steel $$V_s = MIN[V_{s,a}, V_{s,b}]$$ $$V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$$ $$V_s = 38.17 \text{ kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\, (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((75.849 \text{ kip}) + (38.17 \text{ kip}))$$ $$\phi V_n = 74.112 \text{ kip}$$	
	Considering x-direction: $V_{max} = 3.5922 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(3.5922 \text{ kip})}{(74.112 \text{ kip})}$$ $$Ratio = 0.04847$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $V_{max} = 0.029696 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.029696 \text{ kip})}{(74.112 \text{ kip})}$$ $$Ratio = 0.00040069$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$ $$S_m = 4580.4 \text{ in}^3$$	

$$S_m = 4580.4\ \text{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 62.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$

$$\phi M_n = 62.027\ \text{kipft}$$

Considering x-direction:

$M_{max} = 11.881\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.881\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.19155$$

Status: **PASS**
Ratio: **0.190**

Considering z-direction:

$M_{max} = 0.088783\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.088783\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.0014314$$

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