Your Project Calculations

Project Name: 100TitleDr-RevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=100TitleDr-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=gE8wZcj2FvXLHQ0ZQOg0ZfkQtPXjKzGvUzZYoFgX5pf47j36YwUcPzKpQ1GRphSC

Array Specification

Product:	Beam
Unique ID:	4P-19.75-6TOP-XD-45-L-5Hx10W-J25C
Duty Classification:	XD
Module Width:	45.00 in
Module Length:	90.00in
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:	11.64 ft
Total Frame Length:	74.25 ft
Frame Weight:	3694 lbs
Array Dimensions N/S:	18.96 ft
Array Dimensions E/W:	75.83 ft
Rail Length:	227.50 in
Rail Spacing:	3.75 ft
Rail Check:	

Support Specifications

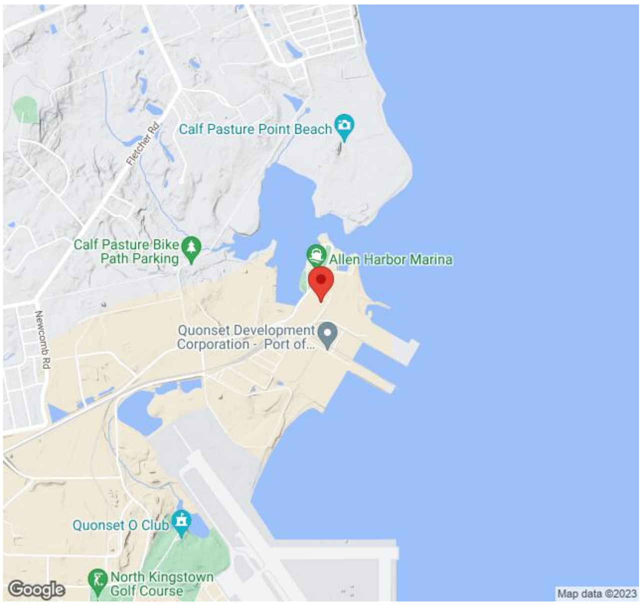
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	10.83 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.50 ft Pile 2: 8.50 ft Pile 3: 8.50 ft Pile 4: 8.50 ft
Foundation Volume:	8.901 y^3
Foundation Result:	PASSED

Site Info

Risk Category:	I
Exposure:	D
Soil Classification:	sand
Site Location:	100 Tidal Dr, North Kingstown, RI 02852, USA
Wind Speed:	118 mph
Snow Load:	30 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.016067 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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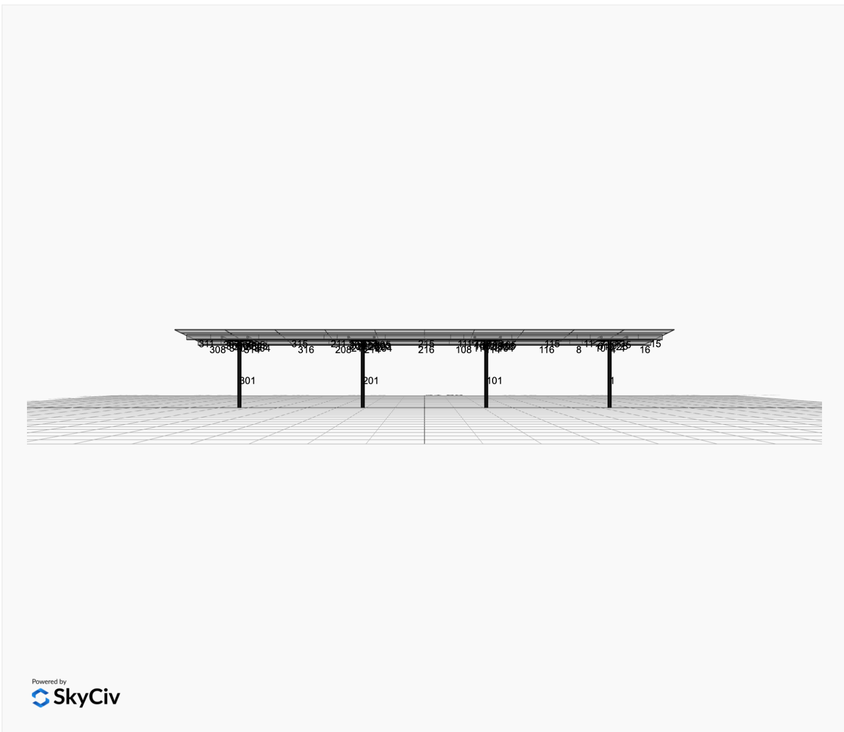
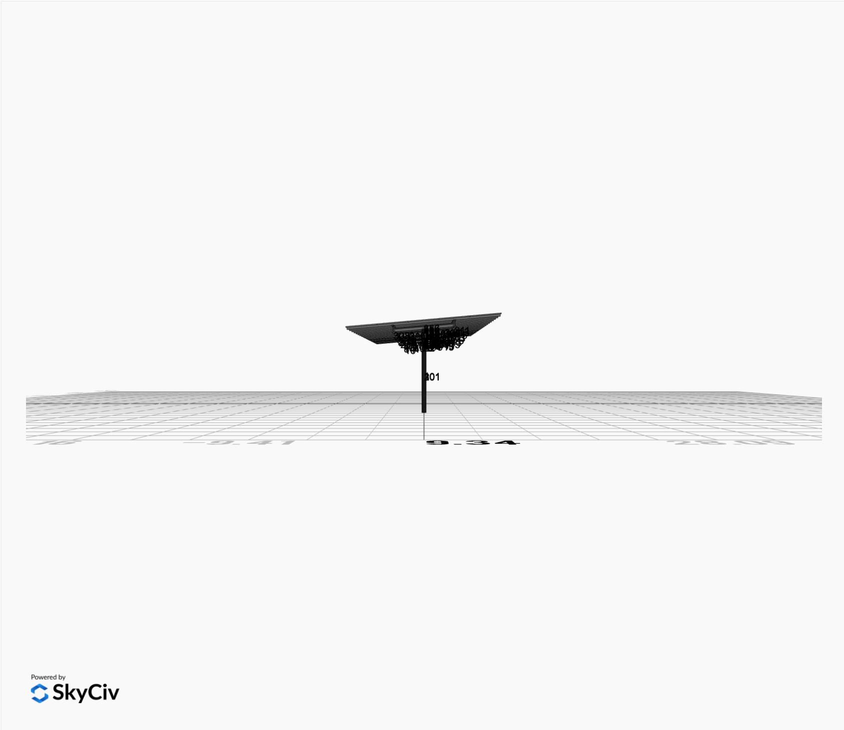
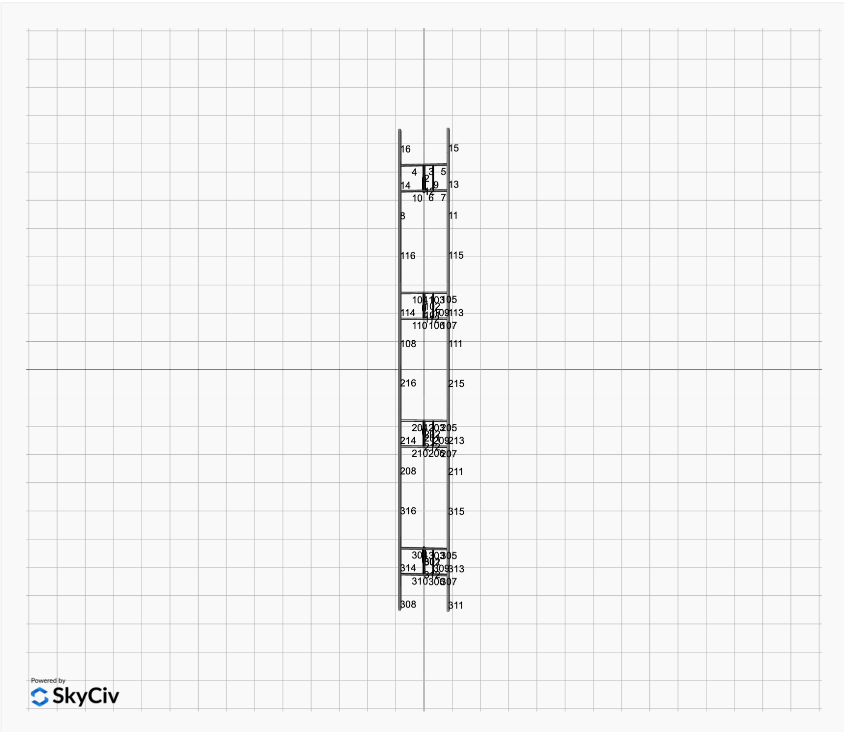
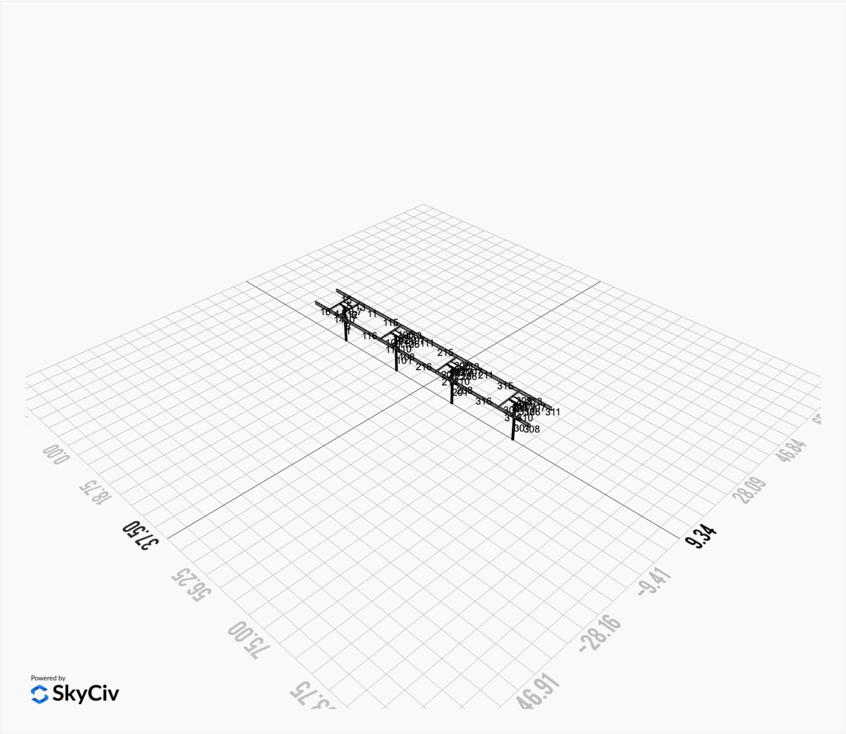
Design Notes:

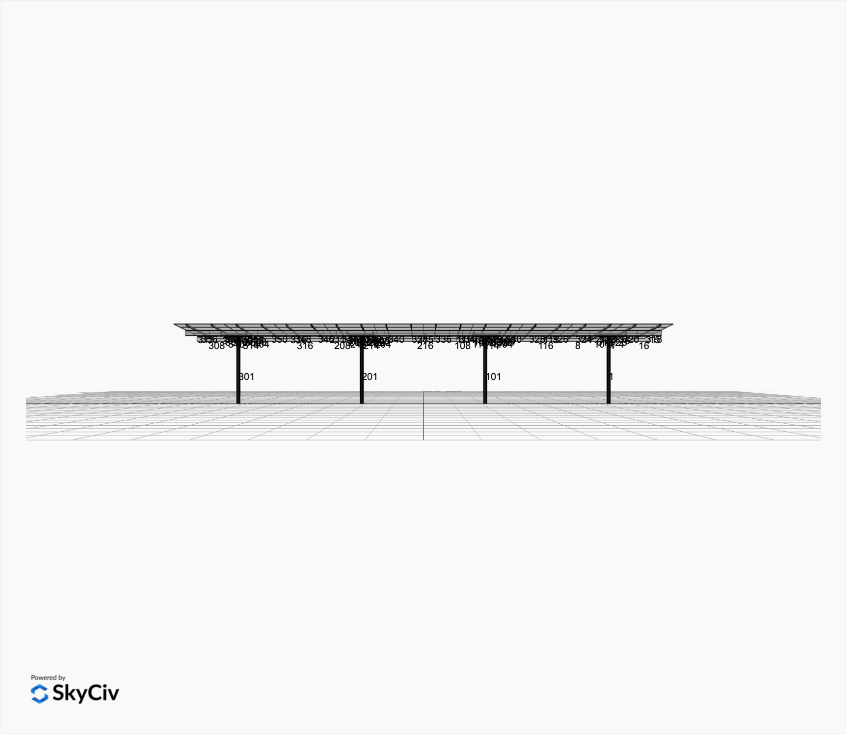
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



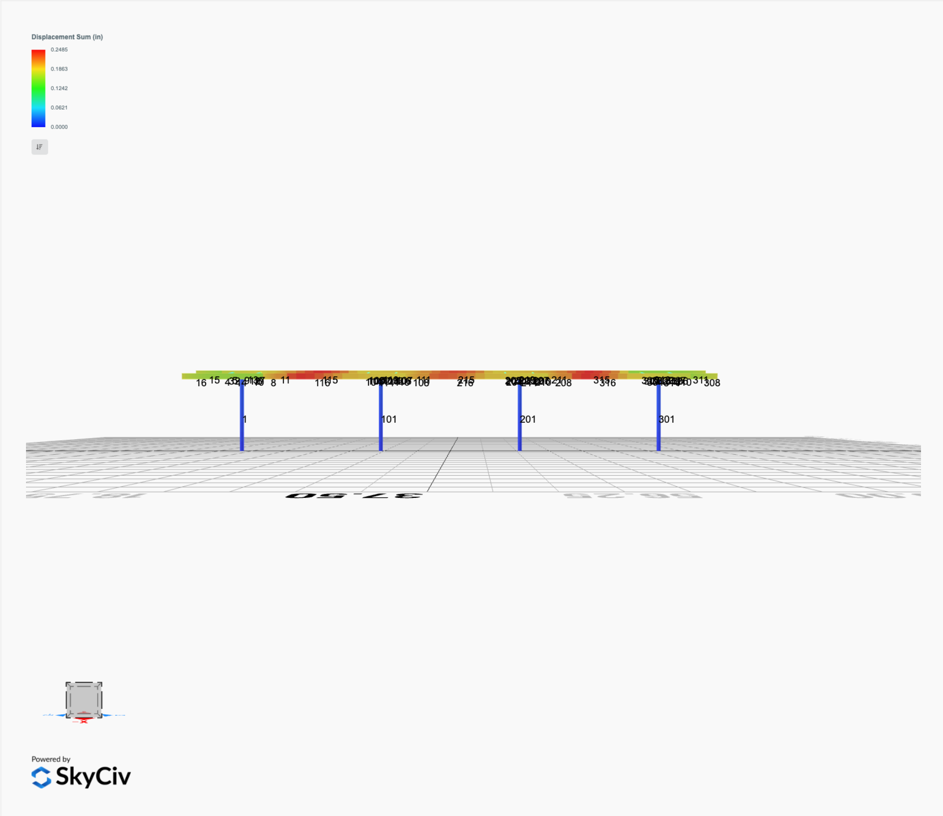


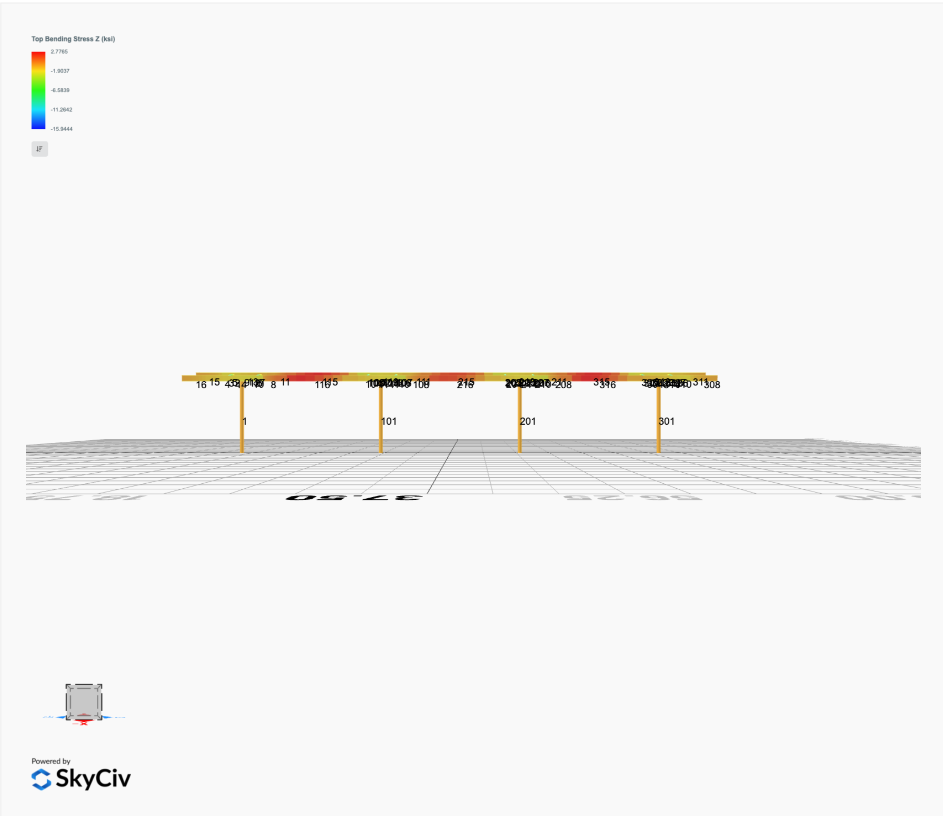




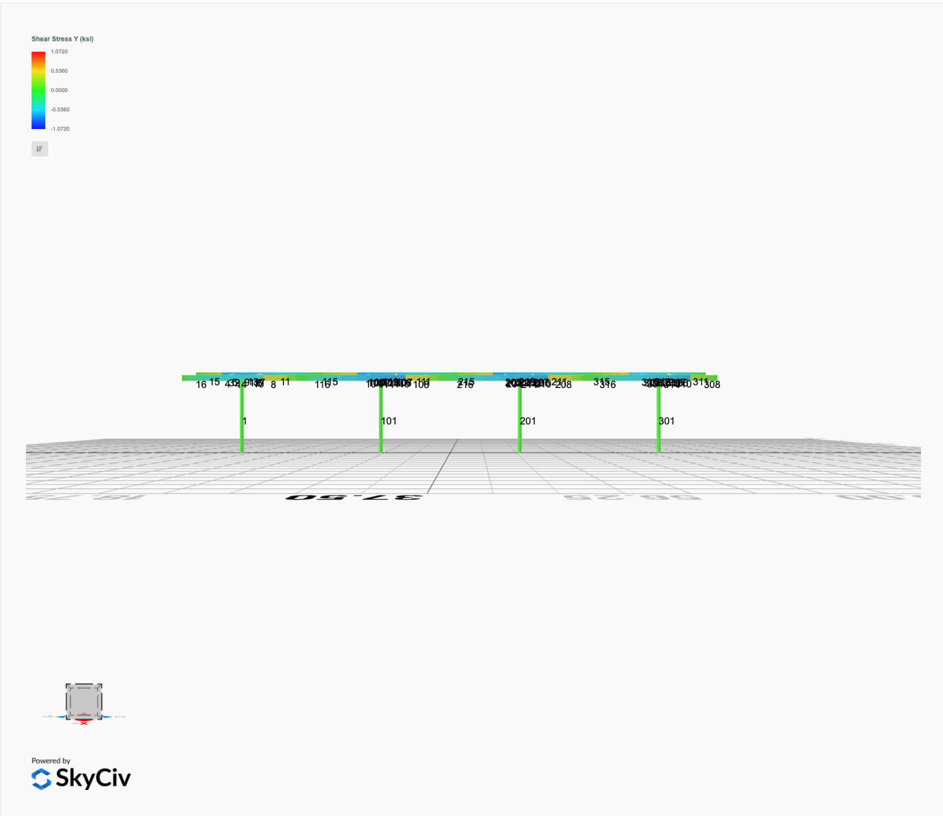


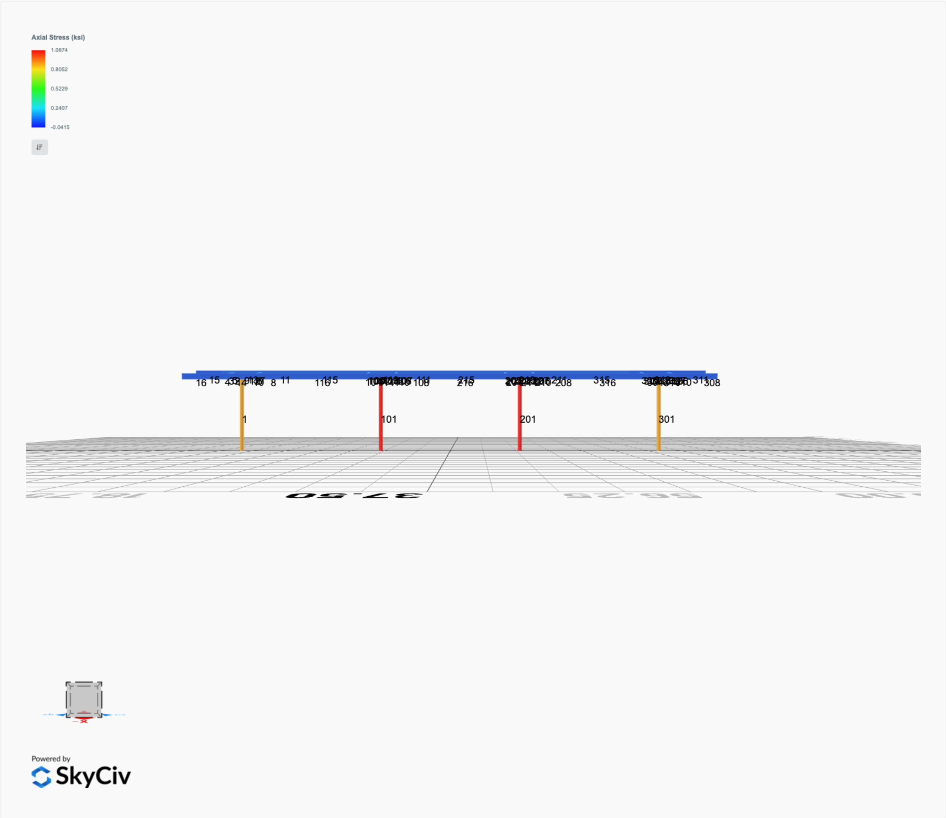
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
2.9472
1.4742
0.0011
-1.4719
-2.9449
1
101
201
301
Powered by
SkyCiv


Shear Stress Y (ksi)
1.0720
0.5360
0.0000
-0.5360
-1.0720
1
101
201
301
Powered by
SkyCiv


Axial Stress (ksi)
1.0874
0.8052
0.5229
0.2407
-0.0415
1
101
201
301
Powered by
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	0.0018	2.3537	0.0220	0.0756	-0.0009	0.0155
ULS: 2. D + L	0.0018	2.3537	0.0220	0.0756	-0.0009	0.0155
ULS: 3. D + (S or Lr or R)	0.0069	7.5497	0.0835	0.2870	-0.0034	-0.0278
ULS: 3. D + (S or Lr or R)	0.0018	2.3537	0.0220	0.0756	-0.0009	0.0155
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0057	6.2507	0.0682	0.2341	-0.0028	-0.0169
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0018	2.3537	0.0220	0.0756	-0.0009	0.0155
ULS: 5b. D + 0.7E	0.0018	2.3537	0.0220	0.0756	-0.0009	0.0155
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0057	6.2507	0.0682	0.2341	-0.0028	-0.0169
ULS: 8. 0.6D + 0.7E	0.0011	1.4122	0.0132	0.0453	-0.0005	0.0093
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4934	7.8734	0.0899	0.3079	-0.0212	6.9333
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4934	7.8734	0.0899	0.3079	-0.0212	6.9333
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1232	0.8666	0.0071	0.0246	-0.0004	4.3237
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3372	-1.1547	-0.0263	-0.0877	0.0205	-15.6244
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3658	10.3905	0.1191	0.4084	-0.0180	5.1714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3658	10.3905	0.1191	0.4084	-0.0180	5.1714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0967	5.1354	0.0570	0.1959	-0.0024	3.2142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2572	3.6195	0.0319	0.1117	0.0133	-11.7469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3696	6.4935	0.0729	0.2498	-0.0161	5.2039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3696	6.4935	0.0729	0.2498	-0.0161	5.2039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0929	1.2384	0.0109	0.0373	-0.0005	3.2467
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2534	-0.2776	-0.0142	-0.0469	0.0152	-11.7144
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4942	6.9319	0.0811	0.2777	-0.0209	6.9271
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4942	6.9319	0.0811	0.2777	-0.0209	6.9271
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1225	-0.0749	-0.0017	-0.0056	-0.0001	4.3175
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3365	-2.0961	-0.0351	-0.1179	0.0209	-15.6306

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
Axial	15.7378
Shear X	-0.8255
Shear Z	0.1823
Moment X	0.6294
Moment Z	27.4997

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
Axial	10.3905
Shear X	-0.4942
Shear Z	0.1191
Moment X	0.4084
Moment Z	15.6306

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	-0.0018	2.6686	-0.0022	-0.0077	0.0004	0.0502
ULS: 2. D + L	-0.0018	2.6686	-0.0022	-0.0077	0.0004	0.0502
ULS: 3. D + (S or Lr or R)	-0.0069	8.7376	-0.0085	-0.0294	0.0014	0.1058
ULS: 3. D + (S or Lr or R)	-0.0018	2.6686	-0.0022	-0.0077	0.0004	0.0502
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0057	7.2204	-0.0069	-0.0240	0.0011	0.0919
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0018	2.6686	-0.0022	-0.0077	0.0004	0.0502
ULS: 5b. D + 0.7E	-0.0018	2.6686	-0.0022	-0.0077	0.0004	0.0502
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0057	7.2204	-0.0069	-0.0240	0.0011	0.0919

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 8. 0.6D + 0.7E	-0.0011	1.6011	-0.0013	-0.0046	0.0002	0.0301
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5533	9.1132	-0.0075	-0.0263	-0.0025	7.7045
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5533	9.1132	-0.0075	-0.0263	-0.0025	7.7045
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1592	0.9272	0.0010	0.0030	-0.0032	4.5615
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3274	-1.4195	-0.0016	-0.0045	0.0096	-16.6807
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4193	12.0539	-0.0108	-0.0379	-0.0010	5.8326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4193	12.0539	-0.0108	-0.0379	-0.0010	5.8326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1151	5.9144	-0.0045	-0.0159	-0.0016	3.4754
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2412	4.1543	-0.0064	-0.0216	0.0080	-12.4563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4154	7.5021	-0.0062	-0.0216	-0.0018	5.7909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4154	7.5021	-0.0062	-0.0216	-0.0018	5.7909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1190	1.3626	0.0002	0.0003	-0.0023	3.4337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2451	-0.3975	-0.0017	-0.0053	0.0073	-12.4980
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5526	8.0458	-0.0066	-0.0232	-0.0027	7.6844
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5526	8.0458	-0.0066	-0.0232	-0.0027	7.6844
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1600	-0.1402	0.0019	0.0061	-0.0034	4.5414
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3281	-2.4869	-0.0007	-0.0015	0.0094	-16.7008

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
Axial	18.2834
Shear X	-0.9220
Shear Z	-0.0170
Moment X	-0.0596
Moment Z	29.4176

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
Axial	12.0539
Shear X	-0.5533
Shear Z	-0.0108
Moment X	-0.0379
Moment Z	16.7008

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	-0.0018	2.6686	0.0022	0.0077	-0.0004	0.0502
ULS: 2. D + L	-0.0018	2.6686	0.0022	0.0077	-0.0004	0.0502
ULS: 3. D + (S or Lr or R)	-0.0069	8.7376	0.0085	0.0294	-0.0014	0.1058
ULS: 3. D + (S or Lr or R)	-0.0018	2.6686	0.0022	0.0077	-0.0004	0.0502
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0057	7.2204	0.0069	0.0240	-0.0011	0.0919
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0018	2.6686	0.0022	0.0077	-0.0004	0.0502
ULS: 5b. D + 0.7E	-0.0018	2.6686	0.0022	0.0077	-0.0004	0.0502
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0057	7.2204	0.0069	0.0240	-0.0011	0.0919
ULS: 8. 0.6D + 0.7E	-0.0011	1.6011	0.0013	0.0046	-0.0002	0.0301
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.5533	9.1132	0.0075	0.0263	0.0025	7.7045
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.5533	9.1132	0.0075	0.0263	0.0025	7.7045
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1592	0.9272	-0.0010	-0.0030	0.0032	4.5615
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3274	-1.4195	0.0016	0.0045	-0.0096	-16.6807
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4193	12.0539	0.0108	0.0379	0.0010	5.8326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4193	12.0539	0.0108	0.0379	0.0010	5.8326
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.1151	5.9144	0.0045	0.0159	0.0016	3.4754
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2412	4.1543	0.0064	0.0216	-0.0080	-12.4563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4154	7.5021	0.0062	0.0216	0.0018	5.7909
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4154	7.5021	0.0062	0.0216	0.0018	5.7909

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 uplift Case A only	0.1190	1.3626	-0.0002	-0.0003	0.0023	3.4337
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2451	-0.3975	0.0017	0.0053	-0.0073	-12.4980
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.5526	8.0458	0.0066	0.0232	0.0027	7.6844
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.5526	8.0458	0.0066	0.0232	0.0027	7.6844
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1600	-0.1402	-0.0019	-0.0061	0.0034	4.5414
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3281	-2.4869	0.0007	0.0015	-0.0094	-16.7008

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
Axial	18.2834
Shear X	-0.9220
Shear Z	0.0170
Moment X	0.0596
Moment Z	29.4177

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
Axial	12.0539
Shear X	-0.5533
Shear Z	0.0108
Moment X	0.0379
Moment Z	16.7008

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	0.0018	2.3537	-0.0220	-0.0756	0.0009	0.0155
ULS: 2. D + L	0.0018	2.3537	-0.0220	-0.0756	0.0009	0.0155
ULS: 3. D + (S or Lr or R)	0.0069	7.5497	-0.0835	-0.2870	0.0034	-0.0278
ULS: 3. D + (S or Lr or R)	0.0018	2.3537	-0.0220	-0.0756	0.0009	0.0155
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0057	6.2507	-0.0682	-0.2341	0.0028	-0.0169
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0018	2.3537	-0.0220	-0.0756	0.0009	0.0155
ULS: 5b. D + 0.7E	0.0018	2.3537	-0.0220	-0.0756	0.0009	0.0155
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0057	6.2507	-0.0682	-0.2341	0.0028	-0.0169
ULS: 8. 0.6D + 0.7E	0.0011	1.4122	-0.0132	-0.0453	0.0005	0.0093
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4934	7.8734	-0.0899	-0.3079	0.0212	6.9333
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4934	7.8734	-0.0899	-0.3079	0.0212	6.9333
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1232	0.8666	-0.0071	-0.0246	0.0004	4.3237
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3372	-1.1547	0.0263	0.0877	-0.0205	-15.6244
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3658	10.3905	-0.1191	-0.4084	0.0180	5.1714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3658	10.3905	-0.1191	-0.4084	0.0180	5.1714
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0967	5.1354	-0.0570	-0.1959	0.0024	3.2142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2572	3.6195	-0.0319	-0.1117	-0.0133	-11.7469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3696	6.4935	-0.0729	-0.2498	0.0161	5.2039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3696	6.4935	-0.0729	-0.2498	0.0161	5.2039
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0929	1.2384	-0.0109	-0.0373	0.0005	3.2467
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2534	-0.2776	0.0142	0.0469	-0.0152	-11.7144
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4942	6.9319	-0.0811	-0.2777	0.0209	6.9271
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4942	6.9319	-0.0811	-0.2777	0.0209	6.9271
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1225	-0.0749	0.0017	0.0056	0.0001	4.3175
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3365	-2.0961	0.0351	0.1179	-0.0209	-15.6306

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.

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
Axial	15.7378
Shear X	-0.8255
Shear Z	-0.1823
Moment X	-0.6294
Moment Z	27.5000

Result	Value
Axial	10.3905
Shear X	-0.4942
Shear Z	-0.1191
Moment X	-0.4084
Moment Z	15.6306

Project Details

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

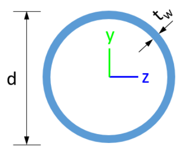
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

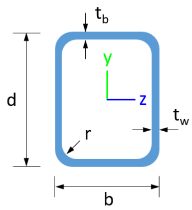
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

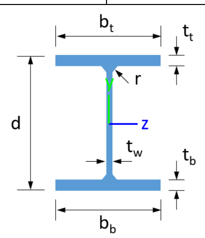
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
7	6in Pipe Sch 40	6.63	0.28					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	62.42	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	22.74	22.74	10.83	-	300	200	1
2	6	2.00	2.00	2.00	-	300	200	1
3	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.18,1.17	300	200	1
4	17	3.75	3.75	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.18,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.39,1.69,1.67,1.67,1.65,1.69	300	200	1
5	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
6	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
7	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
8	20	2.05	2.05	2.05	1.62,1.62,1.62,1.62,1.62,1.62,1.60,1.60,1.35,2.07,1.60,1.60,1.93,2.33,1.61,1.61,1.58,1.71,1.60,1.60,1.99,2.07,1.60,1.60,1.86,2.22	300	200	1
9	3	4.00	4.00	4.00	-	300	200	1
10	17	3.75	3.75	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.38,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.45,1.69,1.67,1.67,1.66,1.69	300	200	1
11	20	2.05	2.05	2.05	1.63,1.63,1.63,1.63,1.63,1.63,1.66,1.66,1.80,2.00,1.66,1.66,2.06,1.86,1.65,1.65,1.67,1.48,1.66,1.66,1.82,1.97,1.66,1.66,2.08,1.84	300	200	1
12	6	2.00	2.00	2.00	-	300	200	1
13	20	1.75	1.75	1.75	1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.65,1.58,1.52,1.65,1.65,1.50,1.56,1.66,1.66,1.64,1.87,1.65,1.65,1.57,1.53,1.65,1.65,1.47,1.56	300	200	1
14	20	1.75	1.75	1.75	1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30	300	200	1
15	20	3.75	3.75	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	20	3.75	3.75	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
17	20	4.00	4.00	4.00	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.20,1.19	300	200	1
18	20	1.75	1.75	1.75	1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30	300	200	1
19	20	4.00	4.00	4.00	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.31,1.20,1.18,1.18,1.20,1.24,1.18,1.18,1.18,1.18,1.18,1.18,1.44,1.20,1.18,1.18,1.20,1.27	300	200	1
20	20	1.75	1.75	1.75	1.68,1.68,1.68,1.68,1.68,1.68,1.70,1.70,1.19,1.49,1.70,1.70,1.54,1.38,1.69,1.69,1.72,1.62,1.70,1.70,1.30,1.48,1.70,1.70,1.56,1.33	300	200	1
21	20	4.00	4.00	4.00	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.11,1.13,1.09,1.09,1.14,1.11,1.09,1.09,1.09,1.07,1.09,1.09,1.11,1.13,1.09,1.09,1.17,1.11	300	200	1
22	20	1.75	1.75	1.75	1.49,1.49,1.49,1.49,1.49,1.49,1.50,1.50,1.58,1.70,1.51,1.51,1.74,1.61,1.49,1.49,1.51,1.40,1.50,1.50,1.58,1.68,1.51,1.51,1.90,1.60	300	200	1
23	20	4.00	4.00	4.00	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.01,1.14,1.08,1.08,1.12,3.29,1.09,1.09,1.08,1.09,1.09,1.09,1.02,1.15,1.08,1.08,1.11,1.03	300	200	1

24	20	1.75	1.75	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.44,1.44,1.15,1.64,1.43,1.43,1.55,2.22,1.44,1.44,1.43,1.48,1.44,1.44,2.13,1.67,1.43,1.43,1.53,2.15	300	200	1
25	20	4.00	4.00	4.00	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.11,1.13,1.09,1.09,1.14,1.11,1.09,1.09,1.09,1.07,1.09,1.09,1.11,1.13,1.09,1.09,1.17,1.11	300	200	1
26	20	1.75	1.75	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.46,1.46,1.52,1.60,1.47,1.47,1.62,1.54,1.46,1.46,1.46,1.38,1.46,1.46,1.52,1.59,1.47,1.47,1.72,1.54	300	200	1
27	20	4.00	4.00	4.00	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.01,1.14,1.08,1.08,1.12,3.28,1.09,1.09,1.08,1.09,1.09,1.09,1.02,1.15,1.08,1.08,1.11,1.03	300	200	1
28	20	1.75	1.75	1.75	1.49,1.48,1.49,1.48,1.48,1.49,1.47,1.47,1.00,1.77,1.47,1.47,1.62,2.14,1.48,1.48,1.46,1.53,1.47,1.47,1.49,1.82,1.47,1.47,1.59,1.63	300	200	1
29	20	4.00	4.00	4.00	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.20,1.19	300	200	1
30	20	1.75	1.75	1.75	1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.65,1.58,1.52,1.65,1.65,1.50,1.56,1.66,1.66,1.64,1.87,1.65,1.65,1.57,1.53,1.65,1.65,1.47,1.56	300	200	1
31	20	4.00	4.00	4.00	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.30,1.20,1.18,1.18,1.20,1.24,1.18,1.18,1.18,1.18,1.18,1.18,1.44,1.20,1.18,1.18,1.20,1.27	300	200	1
32	20	1.75	1.75	1.75	1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30	300	200	1
101	7	22.74	22.74	10.83	-	300	200	1
102	6	2.00	2.00	2.00	-	300	200	1
103	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
104	17	3.75	3.75	3.75	1.68,1.68,1.68,1.67,1.68,1.67,1.67,2.99,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.36,1.69,1.67,1.67,1.66,1.69	300	200	1
105	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
106	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
107	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
108	20	2.05	2.05	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.10,1.09,1.68,2.10,2.10,1.89,1.38,2.10,2.10,2.10,2.07,2.10,2.10,1.27,1.64,2.10,2.10,1.97,1.29	300	200	1
109	3	4.00	4.00	4.00	-	300	200	1
110	17	3.75	3.75	3.75	1.68,1.68,1.68,1.67,1.68,1.67,1.67,1.16,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.43,1.69,1.67,1.67,1.66,1.69	300	200	1
111	20	2.05	2.05	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.02,1.75,2.08,2.08,1.70,1.90,2.08,2.08,2.08,2.32,2.08,2.08,1.99,1.77,2.08,2.08,1.59,1.93	300	200	1
112	6	2.00	2.00	2.00	-	300	200	1
113	20	1.75	1.75	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.46,1.46,1.52,1.60,1.47,1.47,1.62,1.54,1.46,1.46,1.46,1.38,1.46,1.46,1.52,1.59,1.47,1.47,1.72,1.54	300	200	1
114	20	1.75	1.75	1.75	1.49,1.48,1.49,1.48,1.48,1.49,1.47,1.47,1.00,1.77,1.47,1.47,1.62,2.14,1.48,1.48,1.46,1.53,1.47,1.47,1.49,1.82,1.47,1.47,1.59,1.63	300	200	1
115	20	10.20	10.20	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.11,1.15,1.15,1.11,1.12,1.15,1.15,1.15,1.19,1.15,1.15,1.13,1.12,1.15,1.15,1.10,1.13	300	200	1
116	20	10.20	10.20	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.16,1.49,1.11,1.16,1.16,1.12,1.09,1.16,1.16,1.16,1.14,1.16,1.16,1.10,1.10,1.16,1.16,1.13,1.09	300	200	1
201	7	22.74	22.74	10.83	-	300	200	1

202	6	2.00	2.00	2.00	-	300	200	1
203	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
204	17	3.75	3.75	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.16,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.43,1.69,1.67,1.67,1.66,1.69	300	200	1
205	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
206	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
207	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
208	20	2.05	2.05	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.08,2.08,1.02,1.54,2.08,2.08,1.70,1.27,2.07,2.07,2.08,1.97,2.08,2.08,1.16,1.51,2.08,2.08,1.76,1.18	300	200	1
209	3	4.00	4.00	4.00	-	300	200	1
210	17	3.75	3.75	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,2.99,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.36,1.69,1.67,1.67,1.66,1.69	300	200	1
211	20	2.05	2.05	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.06,1.80,1.60,2.06,2.06,1.57,1.72,2.07,2.07,2.06,2.27,2.06,2.06,1.78,1.62,2.06,2.06,1.47,1.74	300	200	1
212	6	2.00	2.00	2.00	-	300	200	1
213	20	1.75	1.75	1.75	1.49,1.49,1.49,1.49,1.49,1.49,1.50,1.50,1.58,1.70,1.51,1.51,1.74,1.61,1.49,1.49,1.51,1.40,1.50,1.50,1.58,1.68,1.51,1.51,1.90,1.60	300	200	1
214	20	1.75	1.75	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.44,1.44,1.15,1.64,1.43,1.43,1.55,2.22,1.44,1.44,1.43,1.48,1.44,1.44,2.13,1.67,1.43,1.43,1.53,2.15	300	200	1
215	20	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.14,1.13,1.15,1.15,1.13,1.14,1.16,1.16,1.15,1.19,1.15,1.15,1.14,1.13,1.15,1.15,1.12,1.14	300	200	1
216	20	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.04,1.12,1.16,1.16,1.14,1.10,1.16,1.16,1.16,1.15,1.16,1.16,1.08,1.12,1.16,1.16,1.14,1.08	300	200	1
301	7	22.74	22.74	10.83	-	300	200	1
302	6	2.00	2.00	2.00	-	300	200	1
303	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
304	17	3.75	3.75	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.38,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.45,1.69,1.67,1.67,1.66,1.69	300	200	1
305	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
306	17	1.42	1.42	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.18,1.17	300	200	1
307	17	2.33	2.33	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
308	20	3.75	3.75	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	3	4.00	4.00	4.00	-	300	200	1
310	17	3.75	3.75	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.18,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.39,1.69,1.67,1.67,1.65,1.69	300	200	1
311	20	3.75	3.75	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
						3	2	

312	6	2.00	2.00	2.00	-	00	00	1
313	20	1.75	1.75	1.75	1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30	300	200	1
314	20	1.75	1.75	1.75	1.68,1.68,1.68,1.68,1.68,1.68,1.70,1.70,1.19,1.49,1.70,1.70,1.54,1.38,1.69,1.69,1.72,1.62,1.70,1.70,1.30,1.48,1.70,1.70,1.56,1.33	300	200	1
315	20	10.20	10.20	10.20	1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.12,1.13,1.14,1.12,1.12,1.15,1.14,1.12,1.12,1.12,1.11,1.12,1.12,1.13,1.14,1.12,1.12,1.16,1.13	300	200	1
316	20	10.20	10.20	10.20	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.83,1.15,1.11,1.11,1.14,1.21,1.11,1.11,1.11,1.12,1.11,1.11,1.33,1.16,1.11,1.11,1.14,1.28	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	85.42	42.30	42.30	75.35	75.35
2	251.01	246.00	27.16	27.16	75.30	75.30
3	151.65	149.42	20.17	14.14	54.12	28.95
4	151.65	136.71	20.17	14.14	54.12	28.95
5	151.65	145.68	20.17	14.14	54.12	28.95
6	151.65	149.42	20.17	14.14	54.12	28.95
7	151.65	145.68	20.17	14.14	54.12	28.95
8	159.30	137.63	46.90	6.46	56.26	44.91
9	75.10	55.95	4.25	4.25	22.53	22.53
10	151.65	136.71	20.17	14.14	54.12	28.95
11	159.30	137.63	46.90	6.46	56.26	44.91
12	251.01	246.00	27.16	27.16	75.30	75.30
13	159.30	139.89	46.90	6.46	56.26	44.91
14	159.30	139.89	46.90	6.46	56.26	44.91
15	159.30	119.60	46.90	6.46	56.26	44.91
16	159.30	119.60	46.90	6.46	56.26	44.91
17	159.30	116.35	46.90	6.46	56.26	44.91
18	159.30	139.89	46.90	6.46	56.26	44.91
19	159.30	116.35	46.90	6.46	56.26	44.91
20	159.30	139.89	46.90	6.46	56.26	44.91
21	159.30	116.35	45.92	6.46	56.26	44.91
22	159.30	139.89	46.90	6.46	56.26	44.91
23	159.30	116.35	43.34	6.46	56.26	44.91
24	159.30	139.89	46.90	6.46	56.26	44.91
25	159.30	116.35	45.92	6.46	56.26	44.91
26	159.30	139.89	46.90	6.46	56.26	44.91
27	159.30	116.35	43.34	6.46	56.26	44.91
28	159.30	139.89	46.90	6.46	56.26	44.91
29	159.30	116.35	46.90	6.46	56.26	44.91
30	159.30	139.89	46.90	6.46	56.26	44.91
31	159.30	116.35	46.90	6.46	56.26	44.91
32	159.30	139.89	46.90	6.46	56.26	44.91
101	251.16	85.42	42.30	42.30	75.35	75.35
102	251.01	246.00	27.16	27.16	75.30	75.30
103	151.65	149.42	20.17	14.14	54.12	28.95
104	151.65	136.71	20.17	14.14	54.12	28.95
105	151.65	145.68	20.17	14.14	54.12	28.95
106	151.65	149.42	20.17	14.14	54.12	28.95
107	151.65	145.68	20.17	14.14	54.12	28.95

108	159.30	137.63	46.90	6.46	56.26	44.91
109	75.10	55.95	4.25	4.25	22.53	22.53
110	151.65	136.71	20.17	14.14	54.12	28.95
111	159.30	137.63	46.90	6.46	56.26	44.91
112	251.01	246.00	27.16	27.16	75.30	75.30
113	159.30	139.89	46.90	6.46	56.26	44.91
114	159.30	139.89	46.90	6.46	56.26	44.91
115	159.30	32.87	21.18	6.46	56.26	44.91
116	159.30	32.87	20.99	6.46	56.26	44.91
201	251.16	85.42	42.30	42.30	75.35	75.35
202	251.01	246.00	27.16	27.16	75.30	75.30
203	151.65	149.42	20.17	14.14	54.12	28.95
204	151.65	136.71	20.17	14.14	54.12	28.95
205	151.65	145.68	20.17	14.14	54.12	28.95
206	151.65	149.42	20.17	14.14	54.12	28.95
207	151.65	145.68	20.17	14.14	54.12	28.95
208	159.30	137.63	46.90	6.46	56.26	44.91
209	75.10	55.95	4.25	4.25	22.53	22.53
210	151.65	136.71	20.17	14.14	54.12	28.95
211	159.30	137.63	46.90	6.46	56.26	44.91
212	251.01	246.00	27.16	27.16	75.30	75.30
213	159.30	139.89	46.90	6.46	56.26	44.91
214	159.30	139.89	46.90	6.46	56.26	44.91
215	159.30	32.87	21.57	6.46	56.26	44.91
216	159.30	32.87	20.03	6.46	56.26	44.91
301	251.16	85.42	42.30	42.30	75.35	75.35
302	251.01	246.00	27.16	27.16	75.30	75.30
303	151.65	149.42	20.17	14.14	54.12	28.95
304	151.65	136.71	20.17	14.14	54.12	28.95
305	151.65	145.68	20.17	14.14	54.12	28.95
306	151.65	149.42	20.17	14.14	54.12	28.95
307	151.65	145.68	20.17	14.14	54.12	28.95
308	159.30	119.60	46.90	6.46	56.26	44.91
309	75.10	55.95	4.25	4.25	22.53	22.53
310	151.65	136.71	20.17	14.14	54.12	28.95
311	159.30	119.60	46.90	6.46	56.26	44.91
312	251.01	246.00	27.16	27.16	75.30	75.30
313	159.30	139.89	46.90	6.46	56.26	44.91
314	159.30	139.89	46.90	6.46	56.26	44.91
315	159.30	32.87	21.38	6.46	56.26	44.91
316	159.30	32.87	21.38	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.184	0.650	0.032	0.011	0.002	0.653	#16	0.607	Not Required	Pass
2	0.001	0.472	0.030	0.099	0.005	0.494	#21	0.083	Not Required	Pass
3	0.002	0.697	0.006	0.069	0.002	0.699	#21	0.071	Not Required	Pass
4	0.001	0.675	0.026	0.068	0.006	0.698	#21	0.126	Not Required	Pass
5	0.002	0.432	0.021	0.069	0.005	0.434	#21	0.117	Not Required	Pass
6	0.002	0.746	0.018	0.075	0.004	0.766	#21	0.071	Not Required	Pass
7	0.002	0.463	0.039	0.074	0.010	0.473	#21	0.117	Not Required	Pass
8	0.001	0.088	0.044	0.045	0.004	0.105	#21	0.157	Not Required	Pass

9	0.004	0.082	0.016	0.001	0.001	0.099	#21	0.317	Not Required	Pass
10	0.002	0.719	0.034	0.072	0.007	0.731	#21	0.126	Not Required	Pass
11	0.001	0.089	0.045	0.047	0.004	0.104	#21	0.157	Not Required	Pass
12	0.000	0.521	0.031	0.106	0.006	0.544	#21	0.083	Not Required	Pass
13	0.001	0.120	0.100	0.061	0.005	0.196	#21	0.134	Not Required	Pass
14	0.000	0.141	0.063	0.043	0.003	0.203	#21	Not Required	Not Required	Pass
15	0.000	0.067	0.029	0.030	0.002	0.097	#21	Not Required	Not Required	Pass
16	0.000	0.065	0.029	0.029	0.002	0.095	#21	Not Required	Not Required	Pass
17	0.001	0.163	0.022	0.022	0.002	0.186	#21	0.306	Not Required	Pass
18	0.000	0.145	0.063	0.044	0.003	0.208	#21	Not Required	Not Required	Pass
19	0.002	0.160	0.024	0.022	0.002	0.167	#21	0.306	Not Required	Pass
20	0.001	0.113	0.098	0.059	0.005	0.186	#21	0.134	Not Required	Pass
21	0.001	0.177	0.018	0.017	0.001	0.193	#21	0.306	Not Required	Pass
22	0.001	0.154	0.092	0.065	0.005	0.246	#21	0.134	Not Required	Pass
23	0.002	0.179	0.021	0.016	0.001	0.197	#21	0.306	Not Required	Pass
24	0.001	0.157	0.083	0.061	0.005	0.240	#21	0.134	Not Required	Pass
25	0.001	0.177	0.018	0.017	0.001	0.193	#21	0.306	Not Required	Pass
26	0.001	0.158	0.083	0.063	0.005	0.242	#21	0.134	Not Required	Pass
27	0.002	0.179	0.021	0.016	0.001	0.197	#21	0.306	Not Required	Pass
28	0.001	0.154	0.092	0.063	0.005	0.247	#21	0.134	Not Required	Pass
29	0.001	0.163	0.022	0.022	0.002	0.186	#21	0.306	Not Required	Pass
30	0.001	0.120	0.100	0.061	0.005	0.196	#21	0.134	Not Required	Pass
31	0.002	0.160	0.024	0.022	0.002	0.167	#21	0.306	Not Required	Pass
32	0.000	0.141	0.063	0.043	0.003	0.203	#21	Not Required	Not Required	Pass
101	0.214	0.695	0.003	0.012	0.000	0.697	#16	0.607	Not Required	Pass
102	0.001	0.581	0.035	0.120	0.006	0.608	#21	0.083	Not Required	Pass
103	0.002	0.841	0.012	0.084	0.002	0.854	#21	0.071	Not Required	Pass
104	0.002	0.819	0.033	0.082	0.007	0.841	#21	0.126	Not Required	Pass
105	0.002	0.521	0.034	0.083	0.009	0.530	#21	0.117	Not Required	Pass
106	0.002	0.838	0.012	0.084	0.003	0.848	#21	0.071	Not Required	Pass
107	0.002	0.520	0.031	0.083	0.008	0.528	#21	0.117	Not Required	Pass
108	0.001	0.054	0.032	0.047	0.004	0.075	#21	0.157	Not Required	Pass
109	0.004	0.086	0.011	0.001	0.000	0.099	#21	0.317	Not Required	Pass
110	0.002	0.813	0.030	0.081	0.007	0.834	#21	0.126	Not Required	Pass
111	0.001	0.059	0.032	0.049	0.004	0.073	#21	0.157	Not Required	Pass
112	0.001	0.576	0.035	0.119	0.006	0.603	#21	0.083	Not Required	Pass
113	0.001	0.158	0.083	0.063	0.005	0.242	#21	0.134	Not Required	Pass
114	0.001	0.154	0.092	0.063	0.005	0.247	#21	0.134	Not Required	Pass
115	0.004	0.339	0.046	0.051	0.004	0.386	#21	0.780	Not Required	Pass
116	0.003	0.328	0.047	0.050	0.004	0.373	#21	0.780	Not Required	Pass
201	0.214	0.695	0.003	0.012	0.000	0.697	#16	0.607	Not Required	Pass
202	0.001	0.576	0.035	0.119	0.006	0.603	#21	0.083	Not Required	Pass
203	0.002	0.838	0.012	0.084	0.003	0.848	#21	0.071	Not Required	Pass
204	0.002	0.813	0.030	0.081	0.007	0.834	#21	0.126	Not Required	Pass
205	0.002	0.520	0.031	0.083	0.008	0.528	#21	0.117	Not Required	Pass
206	0.002	0.841	0.012	0.084	0.002	0.854	#21	0.071	Not Required	Pass
207	0.002	0.521	0.034	0.083	0.009	0.530	#21	0.117	Not Required	Pass
208	0.001	0.067	0.039	0.050	0.004	0.075	#21	0.157	Not Required	Pass
209	0.004	0.086	0.011	0.001	0.000	0.099	#21	0.317	Not Required	Pass
210	0.002	0.819	0.033	0.082	0.007	0.841	#21	0.126	Not Required	Pass
211	0.001	0.072	0.039	0.051	0.004	0.079	#21	0.157	Not Required	Pass
212	0.001	0.581	0.035	0.120	0.006	0.608	#21	0.083	Not Required	Pass
213	0.001	0.154	0.092	0.065	0.005	0.246	#21	0.134	Not Required	Pass
214	0.001	0.157	0.083	0.061	0.005	0.240	#21	0.134	Not Required	Pass

215	0.005	0.291	0.046	0.049	0.004	0.338	#21	0.780	Not Required	Pass
216	0.004	0.275	0.046	0.047	0.004	0.322	#21	0.780	Not Required	Pass
301	0.184	0.650	0.032	0.011	0.002	0.653	#16	0.607	Not Required	Pass
302	0.000	0.521	0.031	0.106	0.006	0.544	#21	0.083	Not Required	Pass
303	0.002	0.746	0.018	0.075	0.004	0.766	#21	0.071	Not Required	Pass
304	0.002	0.719	0.034	0.072	0.007	0.731	#21	0.126	Not Required	Pass
305	0.002	0.463	0.039	0.074	0.010	0.473	#21	0.117	Not Required	Pass
306	0.002	0.697	0.006	0.069	0.002	0.699	#21	0.071	Not Required	Pass
307	0.002	0.432	0.021	0.069	0.005	0.434	#21	0.117	Not Required	Pass
308	0.000	0.065	0.029	0.029	0.002	0.095	#21	Not Required	Not Required	Pass
309	0.004	0.082	0.016	0.001	0.001	0.099	#21	0.317	Not Required	Pass
310	0.001	0.675	0.026	0.068	0.006	0.698	#21	0.126	Not Required	Pass
311	0.000	0.067	0.029	0.030	0.002	0.097	#21	Not Required	Not Required	Pass
312	0.001	0.472	0.030	0.099	0.005	0.494	#21	0.083	Not Required	Pass
313	0.000	0.145	0.063	0.044	0.003	0.208	#21	Not Required	Not Required	Pass
314	0.001	0.113	0.098	0.059	0.005	0.186	#21	0.134	Not Required	Pass
315	0.004	0.348	0.046	0.047	0.004	0.392	#21	0.780	Not Required	Pass
316	0.003	0.337	0.047	0.045	0.004	0.384	#21	0.780	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

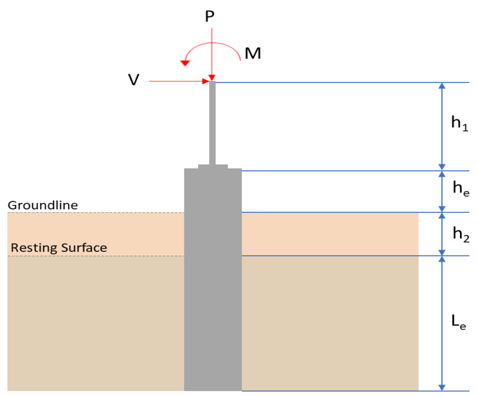
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.391	15.738
V_x (kip)	-0.494	-0.825
V_z (kip)	0.119	0.182
M_x (kipft)	0.408	0.629
M_z (kipft)	15.631	27.500

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.494\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.16467\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.631 \text{ kipft}) + ((-0.494 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.2103 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.0886 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.119 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.039667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.408 \text{ kipft}) + ((0.119 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.136 \text{ kipft/ft}$$

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:
$L_{e,z} = 3.0551 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.0886 \text{ ft}), (3.0551 \text{ ft})]$$

$$L_{e,req} = 8.089 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.089 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.95165$$

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

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

$$q = \frac{(10.391 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.47\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.47\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.73501$$

Status: **PASS**
Ratio: **0.740**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.16467\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2103\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2103\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.16467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (5.2103\ \mathrm{kipft/ft})) + (4 \times (-0.16467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.7743\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.2103\ \mathrm{kipft/ft})) + (3 \times (-0.16467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (5.2103\ \mathrm{kipft/ft})) + (2 \times (-0.16467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.35193\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.2103\ \mathrm{kipft/ft})) + ((-0.16467\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.1768\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7743\ \mathrm{ft})}{2}$$

$$p_a = 0.43307\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.35193\ \mathrm{kip/ft^2}\right)}{\left(0.43307\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.81264$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1768\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92297$$

Status: PASS
Ratio: 0.920

Considering z-direction:

$H_o = 0.039667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.136\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.136\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.136\ \mathrm{kipft/ft})) + (4 \times (0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.108\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.136\ \mathrm{kipft/ft})) + (3 \times (0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.136\ \mathrm{kipft/ft})) + (2 \times (0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.036449\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.136\ \mathrm{kipft/ft})) + ((0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.079466\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.108\ \mathrm{ft})}{2}$$

$$p_a = 0.4581\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.036449\ \mathrm{kip/ft^2}\right)}{\left(0.4581\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.079566$$

Status: PASS
Ratio: 0.080

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

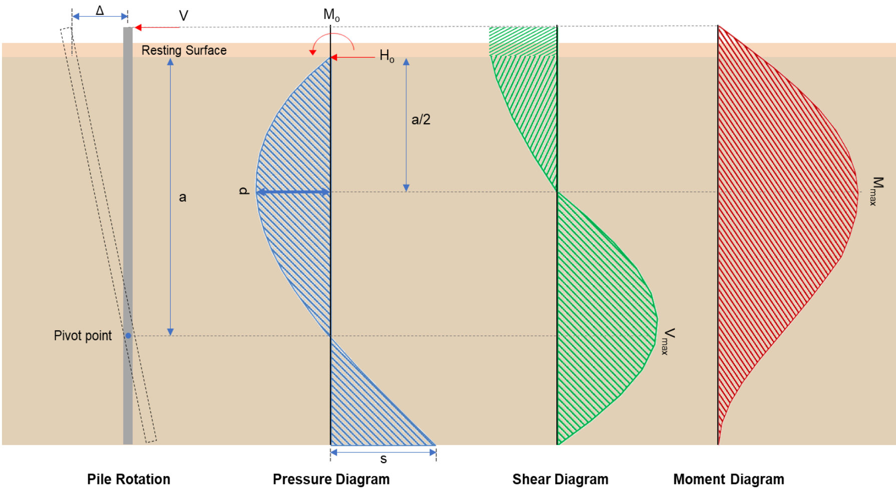
$$Ratio = \frac{s}{}$$

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

$$Ratio = \frac{(0.079466\ \mathrm{kip/ft^2})}{(1.275\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.062326$$

Status: **PASS**
Ratio: **0.060**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.825\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.275\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.5\ \mathrm{kipft}) + ((-0.825\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.1667\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.1667\ \mathrm{kipft/ft})}{(-0.275\ \mathrm{kip/ft})}$$

$$E = 33.333\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1667\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.275\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (9.1667\ \mathrm{kipft/ft})) + (4 \times (-0.275\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.7696\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.275\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (33.333\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7696\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (33.333\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7696\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.2778 \text{ kip}$$

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

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

$$M_{max} = ((-0.275 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(33.333 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 26.038 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.182 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.060667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.629 \text{ kipft}) + ((0.182 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.20967 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.20967 \text{ kipft/ft})}{(0.060667 \text{ kip/ft})}$$

$$E = 3.456 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20967 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (0.060667 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.20967 \text{ kipft/ft})) + (4 \times (0.060667 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1067 \text{ ft}$$

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

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

$$V_{max} = ((0.060667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1067 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1067 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.25259 \text{ kip}$$

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

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

$$M_{max} = ((0.060667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.456 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.9359 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.738 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.684 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\,[(-44.684 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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,

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

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

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

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,

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 1492.5\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(15.738\text{ kip})}{(1492.5\text{ kip})}$$ $$Ratio = 0.010545$$	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 $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 203.86\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$, $P = 15.738\text{ kip} \rightarrow 15738\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + \frac{(15738\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 84.214\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 237.06\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\text{ kip}), (84.214\text{ kip}), (237.06\text{ kip})\right]$$

$$V_c = 84.214\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{s,a} = 454.3\ \mathrm{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3\ \mathrm{kip}), (38.17\ \mathrm{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.214\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 79.55\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 6.2778\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.2778\ \mathrm{kip})}{(79.55\ \mathrm{kip})}$$

$$Ratio = 0.078916$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$V_{max} = 0.25259\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.25259\ \mathrm{kip})}{(79.55\ \mathrm{kip})}$$

$$Ratio = 0.0031752$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

$$\phi M_{n,1} = 67.947kipft$$

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

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

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

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 26.038 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(26.038 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.38321$$

Status: **PASS**
Ratio: **0.380**

Considering z-direction:

$M_{max} = 0.9359 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.9359 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.013774$$

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

REFERENCES	CALCULATIONS	RESULTS

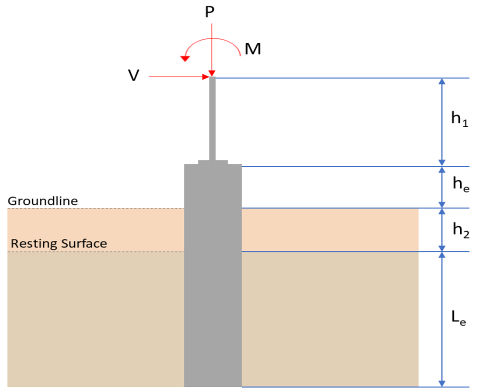
SkyCiv Foundation Design

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
$L = 8.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.054	18.283
V_x (kip)	-0.553	-0.922
V_z (kip)	-0.011	-0.017
M_x (kipft)	-0.038	-0.060
M_z (kipft)	16.701	29.418

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.553\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.18433\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.701\ \mathrm{kipft}) + ((-0.553\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 5.567\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.2261\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.011\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.0036667\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038\ \mathrm{kipft}) + ((-0.011\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.012667\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.0692\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.2261\ \mathrm{ft}), (1.0692\ \mathrm{ft})]$$

$$L_{e,req} = 8.226\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.226\ \mathrm{ft})}{(8.5\ \mathrm{ft})}$$

$$Ratio = 0.96776$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(12.054\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.7053\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.7053\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.85265$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.18433\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.567\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.567\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.18433\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (5.567\ \mathrm{kipft/ft})) + (4 \times (-0.18433\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.7786\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.567\ \mathrm{kipft/ft})) + (3 \times (-0.18433\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (5.567\ \mathrm{kipft/ft})) + (2 \times (-0.18433\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.37088\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.567\ \mathrm{kipft/ft})) + ((-0.18433\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.248\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7786\ \mathrm{ft})}{2}$$

$$p_a = 0.43339\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.37088\ \mathrm{kip/ft^2}\right)}{\left(0.43339\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85576$$

Status: **PASS**
Ratio: **0.860**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.248\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97885$$

Status: PASS
Ratio: 0.980

Considering z-direction:

$H_o = -0.0036667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.012667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.012667\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.012667\ \mathrm{kipft/ft})) + (4 \times (-0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.1067\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.012667\ \mathrm{kipft/ft})) + (3 \times (-0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.012667\ \mathrm{kipft/ft})) + (2 \times (-0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.0012293\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.012667\ \mathrm{kipft/ft})) + ((-0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})]}{(8.5\ \mathrm{ft})^2}$$

$$s = -0.00076096\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1067\ \mathrm{ft})}{2}$$

$$p_a = 0.458\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0012293\ \mathrm{kip/ft^2}\right)}{\left(0.458\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0026841$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

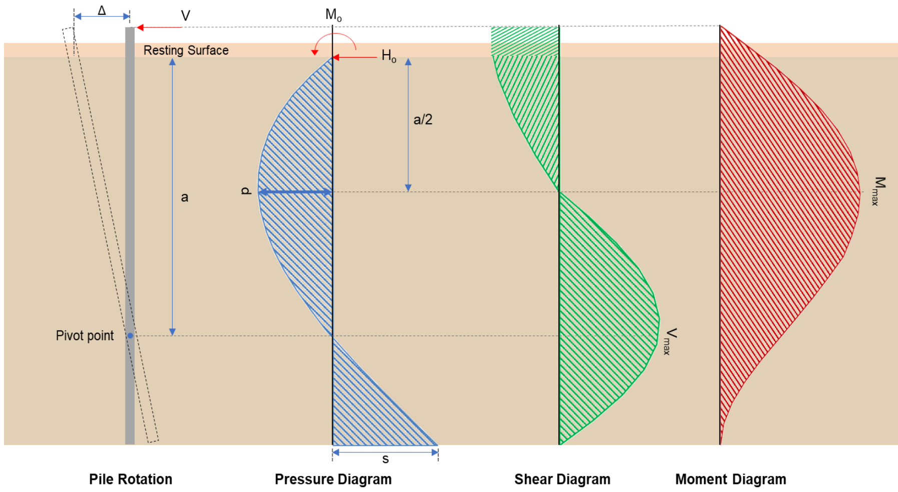
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00076096\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00059683$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.922\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.30733\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.418\ \mathrm{kipft}) + ((-0.922\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.806\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.806\ \mathrm{kipft/ft})}{(-0.30733\ \mathrm{kip/ft})}$$

$$E = 31.907\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.806\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.30733\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (9.806\ \mathrm{kipft/ft})) + (4 \times (-0.30733\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.7735\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.30733\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.907\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7735\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.907\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7735\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.7411 \text{ kip}$$

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

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

$$M_{max} = ((-0.30733 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(31.907 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 27.932 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.017 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0056667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.06 \text{ kipft}) + ((-0.017 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.02 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.02 \text{ kipft/ft})}{(-0.0056667 \text{ kip/ft})}$$

$$E = 3.5294 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.02 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.0056667 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.02 \text{ kipft/ft})) + (4 \times (-0.0056667 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1031 \text{ ft}$$

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

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

$$V_{max} = ((-0.0056667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1031 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1031 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.02385 \text{ kip}$$

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

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

$$M_{max} = ((-0.0056667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.5294 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.088504 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.283 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.604 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.604 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.283\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$

$$Ratio = 0.01225$$

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 203.86\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 18.283\ \mathrm{kip} \rightarrow 18283\ \mathrm{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(18283\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 84.646\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 237.06\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (84.646\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 84.646 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

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

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.646 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.831 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.7411 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.7411 \text{ kip})}{(79.831 \text{ kip})}$$

$$Ratio = 0.084442$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$V_{max} = 0.02385 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.02385 \text{ kip})}{(79.831 \text{ kip})}$$

$$Ratio = 0.00029875$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

$$\phi M_{n,1} = 67.947kipft$$

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

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

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

$$\phi M_{n,2} = 632.67\ \mathrm{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947\ \mathrm{kipft}), (632.67\ \mathrm{kipft})]$$

$$\phi M_n = 67.947\ \mathrm{kipft}$$

Considering x-direction:

$M_{max} = 27.932\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(27.932\ \mathrm{kipft})}{(67.947\ \mathrm{kipft})}$$

$$Ratio = 0.41108$$

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

Considering z-direction:

$M_{max} = 0.088504\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.088504\ \mathrm{kipft})}{(67.947\ \mathrm{kipft})}$$

$$Ratio = 0.0013025$$

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

REFERENCES	CALCULATIONS	RESULTS

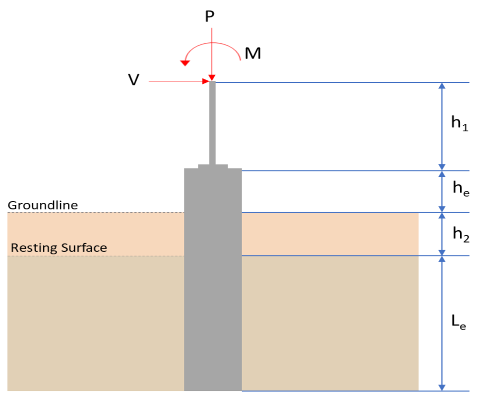
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.054	18.283
V_x (kip)	-0.553	-0.922
V_z (kip)	0.011	0.017
M_x (kipft)	0.038	0.060
M_z (kipft)	16.701	29.418

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.553\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.18433\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.701 \text{ kipft}) + ((-0.553 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.567 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.2261 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.011 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0036667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038 \text{ kipft}) + ((0.011 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.012667 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.2662 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.2261 \text{ ft}), (1.2662 \text{ ft})]$$

$$L_{e,req} = 8.226 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.226 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.96776$$

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

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

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

$$q = \frac{(12.054 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.7053\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.7053\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.85265$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{\left(8.5\ \mathrm{ft}\right)}{\left(36\ \mathrm{in}\right)}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.18433\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.567\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(5.567\ \mathrm{kipft/ft}\right) \times \left(8.5\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.18433\ \mathrm{kip/ft}\right) \times \left(8.5\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(5.567\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.18433\ \mathrm{kip/ft}\right) \times \left(8.5\ \mathrm{ft}\right)\right)}$$

$$a = 5.7786\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times \left[\left(4 \times \left(5.567\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.18433\ \mathrm{kip/ft}\right) \times \left(8.5\ \mathrm{ft}\right)\right)\right]^2}{\left(8.5\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(5.567\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.18433\ \mathrm{kip/ft}\right) \times \left(8.5\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.37088\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times \left[\left(2 \times \left(5.567\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.18433\ \mathrm{kip/ft}\right) \times \left(8.5\ \mathrm{ft}\right)\right)\right]}{\left(8.5\ \mathrm{ft}\right)^2}$$

$$s = 1.248\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(5.7786\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.43339\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.37088\ \mathrm{kip/ft^2}\right)}{\left(0.43339\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.85576$$

Status: **PASS**
Ratio: **0.860**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.248\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97885$$

Status: PASS
Ratio: 0.980

Considering z-direction:

$H_o = 0.0036667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.012667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.012667\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.012667\ \mathrm{kipft/ft})) + (4 \times (0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.1067\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.012667\ \mathrm{kipft/ft})) + (3 \times (0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.012667\ \mathrm{kipft/ft})) + (2 \times (0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.0033775\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.012667\ \mathrm{kipft/ft})) + ((0.0036667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0073704\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1067\ \mathrm{ft})}{2}$$

$$p_a = 0.458\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0033775\ \mathrm{kip/ft^2}\right)}{\left(0.458\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0073743$$

Status: PASS
Ratio: 0.010

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

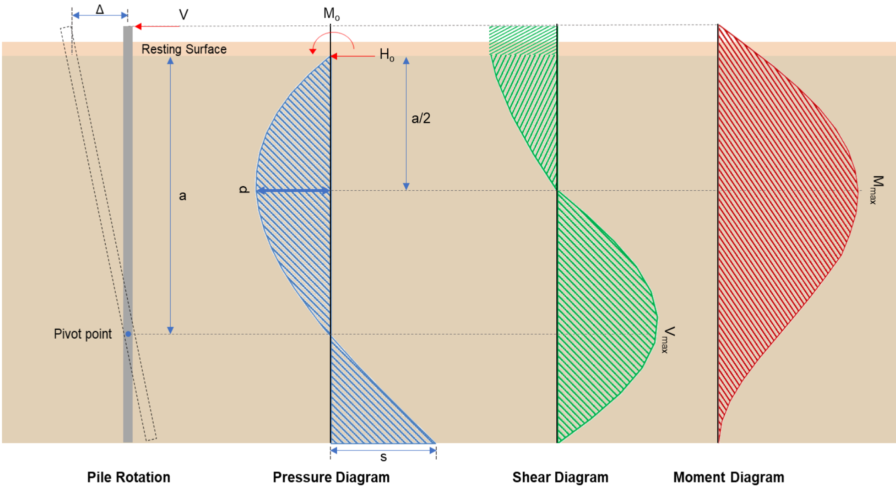
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0073704 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.0057807$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.922 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.30733 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.418 \text{ kipft}) + ((-0.922 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.806 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.806 \text{ kipft/ft})}{(-0.30733 \text{ kip/ft})}$$

$$E = 31.907 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.806 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.30733 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (9.806 \text{ kipft/ft})) + (4 \times (-0.30733 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.7735 \text{ ft}$$

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

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

$$V_{max} = ((-0.30733 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.7735 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.7735 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.7411 \text{ kip}$$

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

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

$$M_{max} = ((-0.30733 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(31.907 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.907 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.7735 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 27.932 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.017 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0056667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.06 \text{ kipft}) + ((0.017 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.02 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.02 \text{ kipft/ft})}{(0.0056667 \text{ kip/ft})}$$

$$E = 3.5294 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.02 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (0.0056667 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.02 \text{ kipft/ft})) + (4 \times (0.0056667 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1031 \text{ ft}$$

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

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

$$V_{max} = ((0.0056667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1031 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1031 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.02385 \text{ kip}$$

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

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

$$M_{max} = ((0.0056667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.5294 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5294 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1031 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.088504 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.283 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.604 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-44.604 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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 $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 1492.5\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(18.283\text{ kip})}{(1492.5\text{ kip})}$$ $$Ratio = 0.01225$$	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 $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,max} = 203.86\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,$P = 18.283\text{ kip} \rightarrow 18283\text{ lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + \frac{(18283\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,a} = 84.646\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,b} = 237.06\text{ kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(203.86\text{ kip}), (84.646\text{ kip}), (237.06\text{ kip})\right]$$	

$$V_c = 84.646\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 454.3\ \text{kip}$$

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

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

$$V_s = MIN\left[(454.3\ \text{kip}), (38.17\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.646\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 79.831\ \text{kip}$$

Considering x-direction:

$V_{max} = 6.7411\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.7411\ \text{kip})}{(79.831\ \text{kip})}$$

$$Ratio = 0.084442$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$V_{max} = 0.02385\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.02385\ \text{kip})}{(79.831\ \text{kip})}$$

$$Ratio = 0.00029875$$

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:
$\phi M_{n,1}$

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

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

$$\phi M_{n,1} = 67.947kipft$$

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

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

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

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 27.932 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(27.932 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.41108$$

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

Considering z-direction:

$M_{max} = 0.088504 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.088504 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.0013025$$

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

REFERENCES	CALCULATIONS	RESULTS

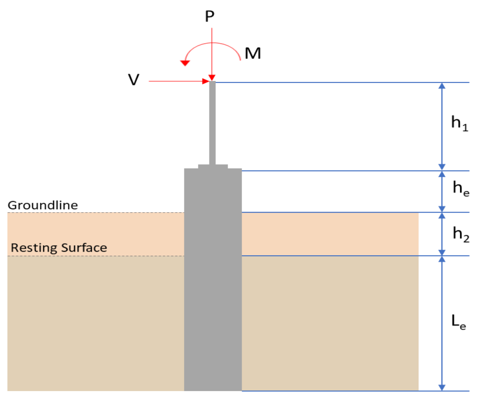
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.391	15.738
V_x (kip)	-0.494	-0.825
V_z (kip)	-0.119	-0.182
M_x (kipft)	-0.408	-0.629
M_z (kipft)	15.631	27.500

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.494\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.16467\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(15.631\ \mathrm{kipft}) + ((-0.494\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 5.2103\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.0886\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.119\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.039667\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.408\ \mathrm{kipft}) + ((-0.119\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.136\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0986\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.0886\ \mathrm{ft}), (2.0986\ \mathrm{ft})]$$

$$L_{e,req} = 8.089\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.089\ \mathrm{ft})}{(8.5\ \mathrm{ft})}$$

$$Ratio = 0.95165$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(10.391\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.47 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.47 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.73501$$

Status: **PASS**
Ratio: **0.740**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.8333$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.16467 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2103 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2103 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.16467 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (5.2103 \text{ kipft/ft})) + (4 \times (-0.16467 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.7743 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.2103 \text{ kipft/ft})) + (3 \times (-0.16467 \text{ kip/ft}) \times (8.5 \text{ ft}))]^{\,2}}{(8.5 \text{ ft})^2 \times [(3 \times (5.2103 \text{ kipft/ft})) + (2 \times (-0.16467 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.35193 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.2103 \text{ kipft/ft})) + ((-0.16467 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.1768 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7743 \text{ ft})}{2}$$

$$p_a = 0.43307 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.35193 \text{ kip/ft}^2\right)}{\left(0.43307 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.81264$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1768\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92297$$

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

Considering z-direction:

$H_o = -0.039667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.136\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.136\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.136\ \mathrm{kipft/ft})) + (4 \times (-0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.108\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.136\ \mathrm{kipft/ft})) + (3 \times (-0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.136\ \mathrm{kipft/ft})) + (2 \times (-0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.01338\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.136\ \mathrm{kipft/ft})) + ((-0.039667\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = -0.008501\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.108\ \mathrm{ft})}{2}$$

$$p_a = 0.4581\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.01338\ \mathrm{kip/ft^2}\right)}{\left(0.4581\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.029207$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

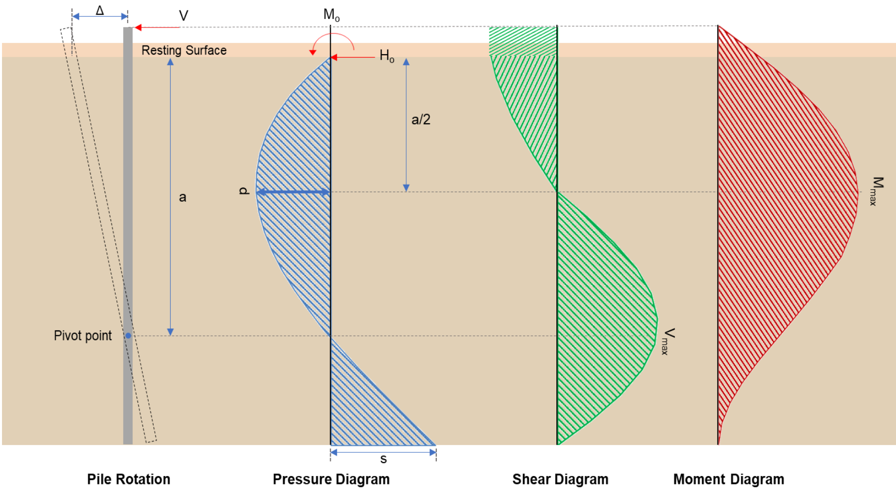
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.008501 \text{ kip/ft}^2\right)}{\left(1.275 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.0066674$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.825 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.275 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.5 \text{ kipft}) + ((-0.825 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.1667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.1667 \text{ kipft/ft})}{(-0.275 \text{ kip/ft})}$$

$$E = 33.333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1667 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.275 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (9.1667 \text{ kipft/ft})) + (4 \times (-0.275 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.7696 \text{ ft}$$

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

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

$$V_{max} = ((-0.275 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.7696 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.7696 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.2778 \text{ kip}$$

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

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

$$M_{max} = ((-0.275 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(33.333 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (33.333 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.7696 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 26.038 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.182 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.060667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.629 \text{ kipft}) + ((-0.182 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.20967 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.20967 \text{ kipft/ft})}{(-0.060667 \text{ kip/ft})}$$

$$E = 3.456 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20967 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.060667 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.20967 \text{ kipft/ft})) + (4 \times (-0.060667 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1067 \text{ ft}$$

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

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

$$V_{max} = ((-0.060667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1067 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1067 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.25259 \text{ kip}$$

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

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

$$M_{max} = ((-0.060667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.456 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.456 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1067 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.9359 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.738 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.684 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.684 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.738\text{ kip})}{(1492.5\text{ kip})}$$

$$Ratio = 0.010545$$

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 $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$,

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 203.86\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$, $P = 15.738\text{ kip} \to 15738\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + \frac{(15738\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 84.214\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 237.06\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\text{ kip}), (84.214\text{ kip}), (237.06\text{ kip})\right]$$

$$V_c = 84.214 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

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

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.214 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.55 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.2778 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.2778 \text{ kip})}{(79.55 \text{ kip})}$$

$$Ratio = 0.078916$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$V_{max} = 0.25259 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.25259 \text{ kip})}{(79.55 \text{ kip})}$$

$$Ratio = 0.0031752$$

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:
$\phi M_{n,1}$

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

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

$$\phi M_{n,1} = 67.947kipft$$

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

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

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

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 26.038 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(26.038 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.38321$$

Status: **PASS**
Ratio: **0.380**

Considering z-direction:

$M_{max} = 0.9359 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.9359 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.013774$$

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