Your Project Calculations

Project Name: MTSOLAR_K0J67FLBBE74

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_K0J67FLBBE74&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=AjpykaGBWx7yMdmlmpuxmWiJj7Ky01juDU66QQ8p6w08oM2ccU7TYpl8MeW8yHeO

Array Specification

Product:	Beam
Unique ID:	5P-19.75-8TOP-HD-45-L-4Hx15W-DFAC
Duty Classification:	HD
Module Width:	41.00 in
Module Length:	74.00in
Number of Rows:	4
Number of Columns:	15
Total Number of Modules:	60
Desired Tilt Angle:	30
Front Edge Clearance:	3
Total Array Height at Tilt:	9.87 ft
Total Frame Length:	94.00 ft
Frame Weight:	3875 lbs
Array Dimensions N/S:	13.83 ft
Array Dimensions E/W:	93.75 ft
Rail Length:	166.00 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

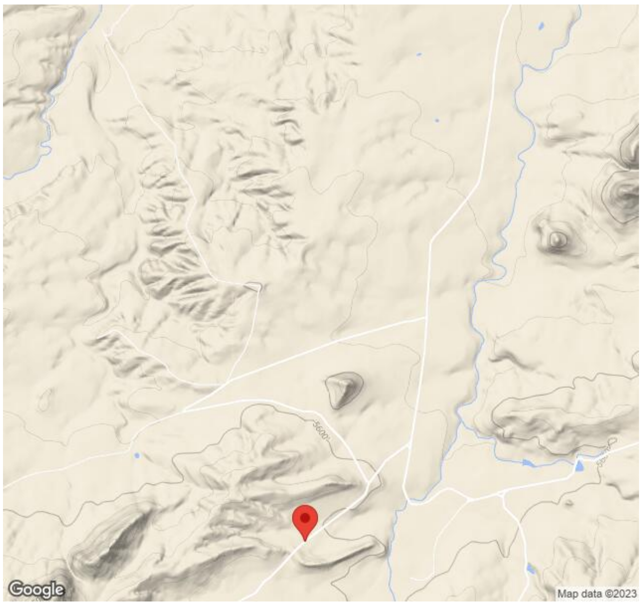
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	6.46 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 7.50 ft Pile 3: 7.75 ft Pile 4: 7.50 ft Pile 5: 7.50 ft
Foundation Volume:	9.883 y^3
Foundation Result:	PASSED
Mount Twist:	0.376095 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	737 Brush Creek Rd, Wheatland, WY 82201, USA
Wind Speed:	102 mph
Snow Load:	25 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.010996 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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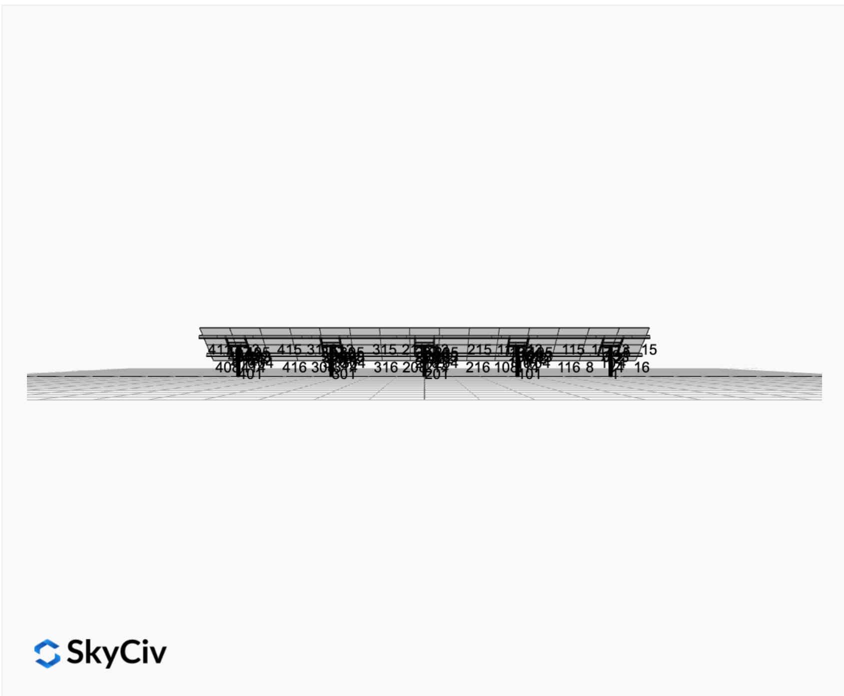
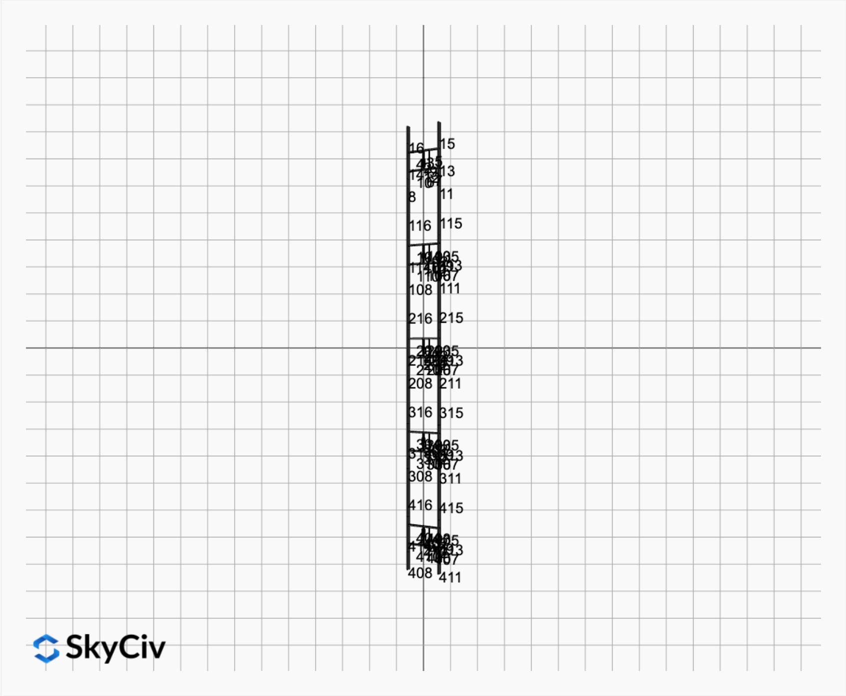
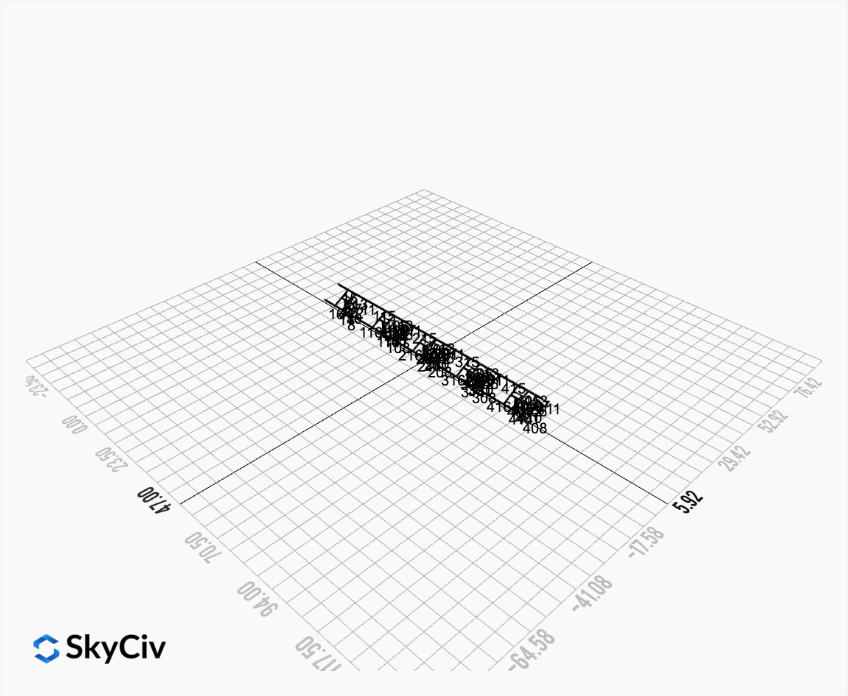
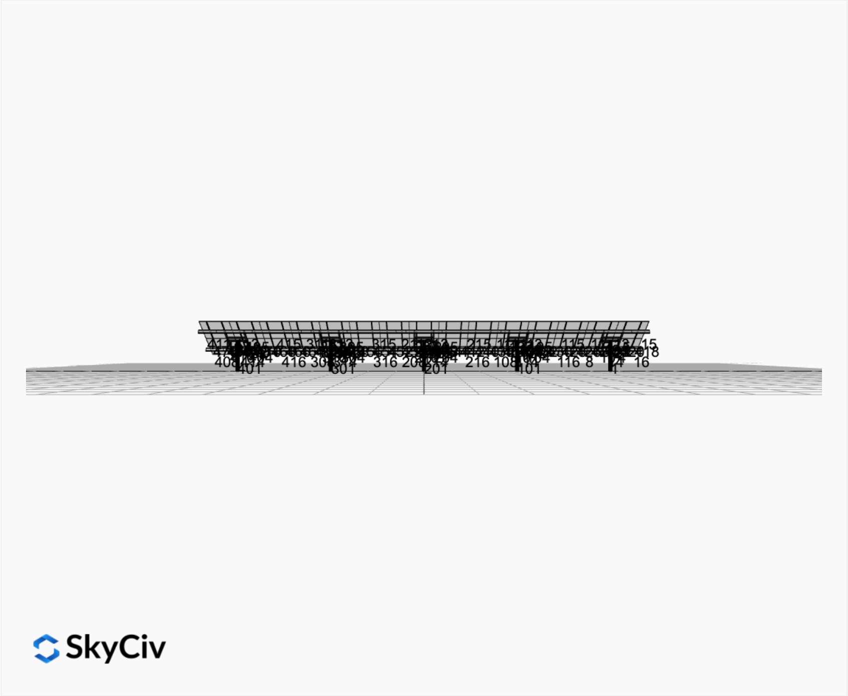
Design Notes:

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

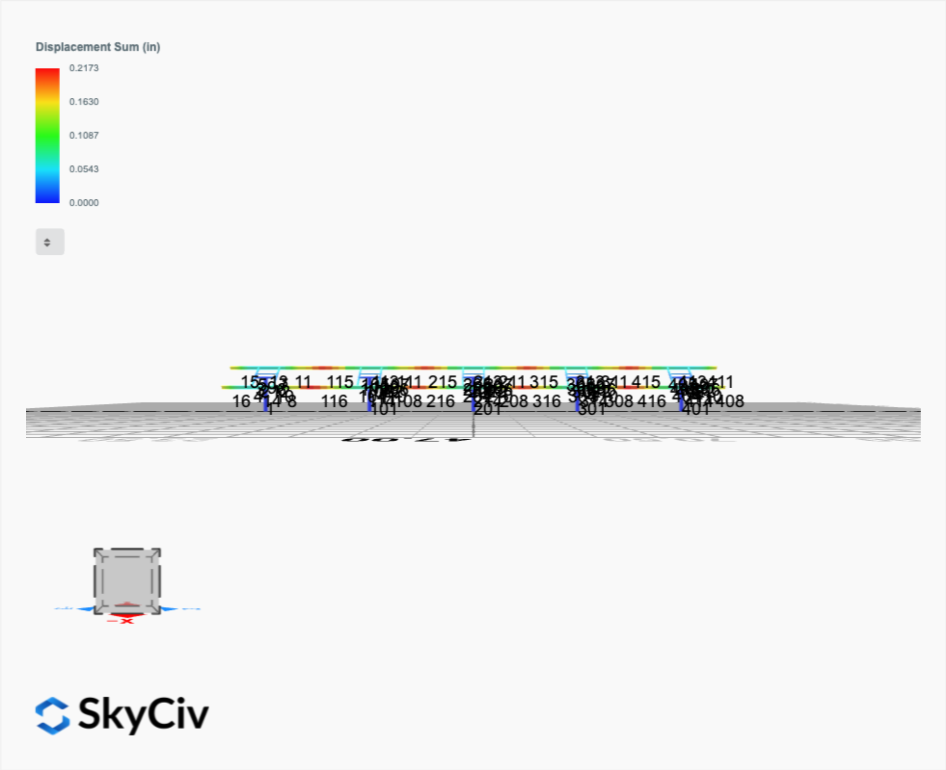


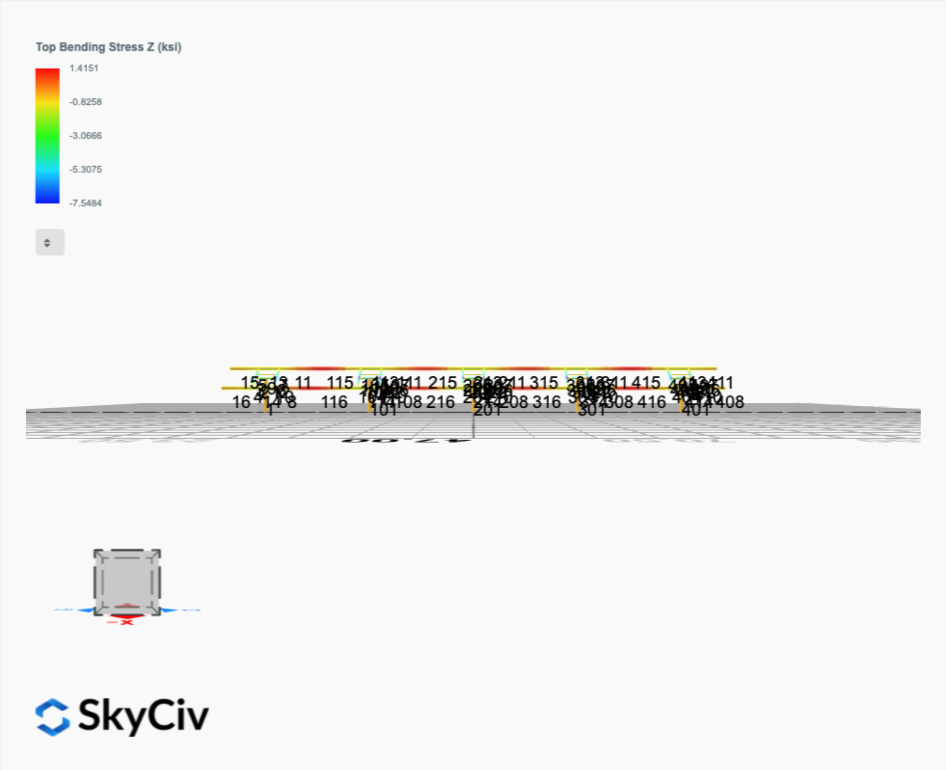


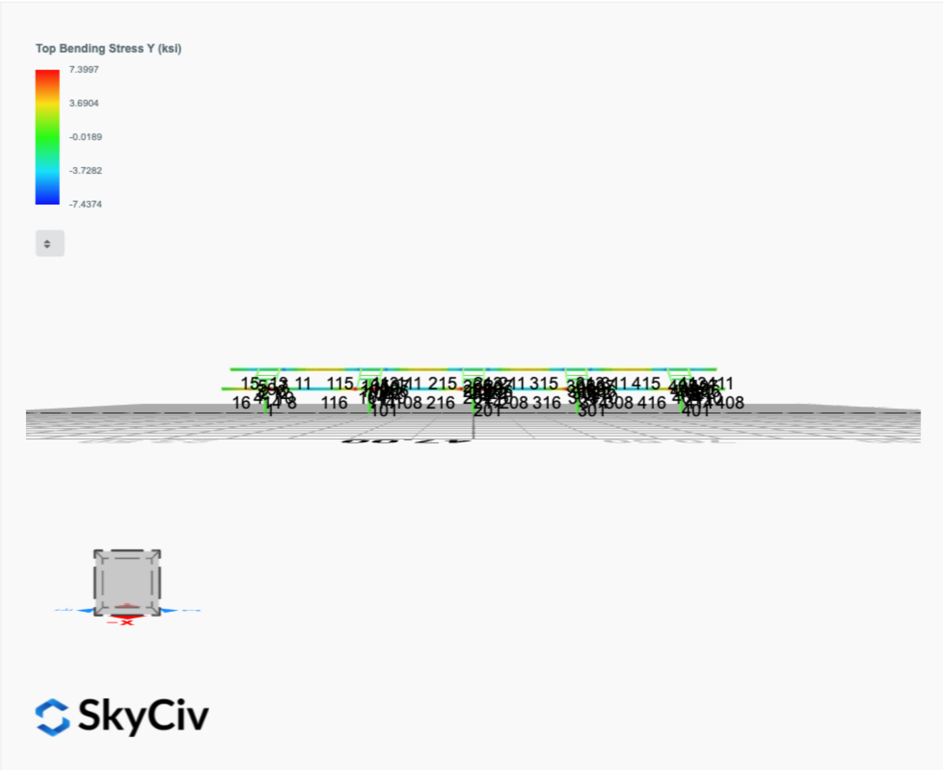


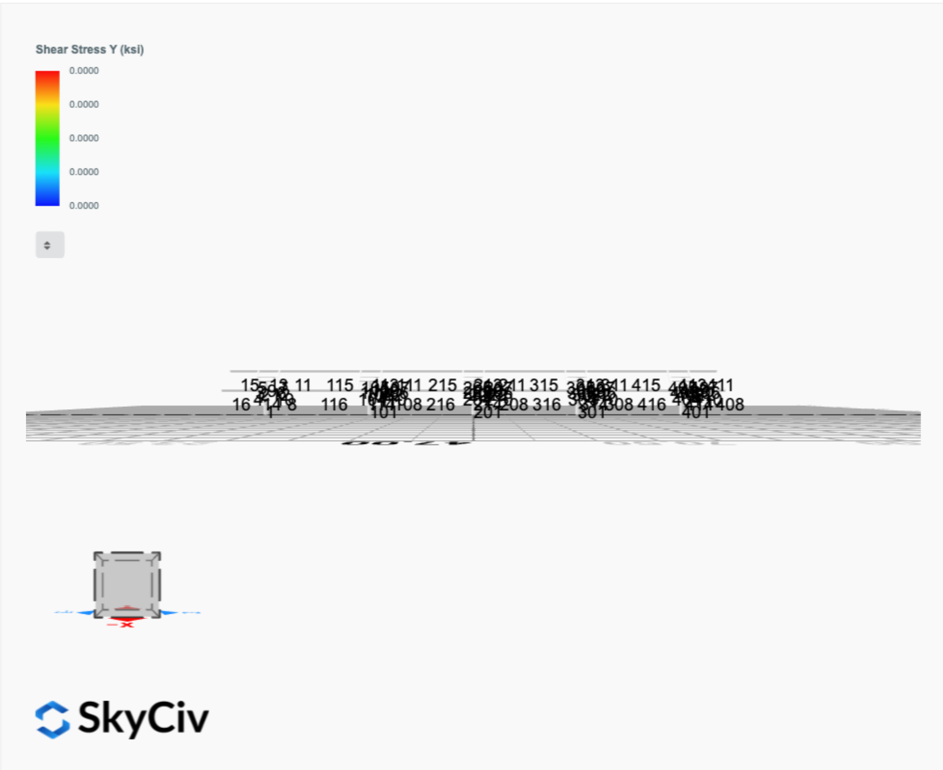


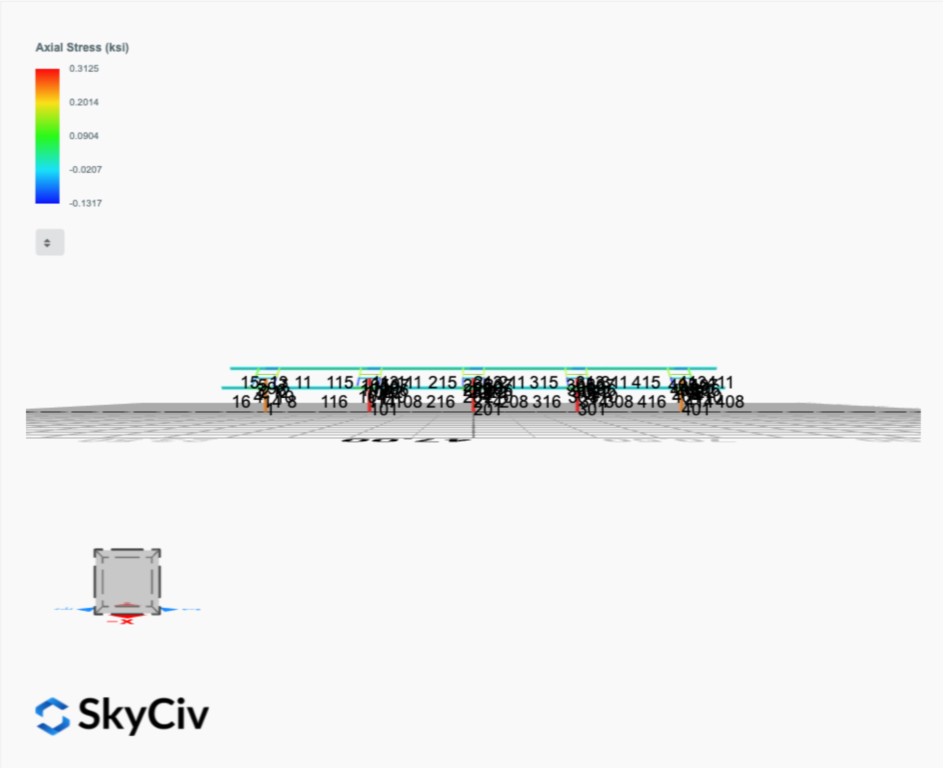
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
7.3997
3.6904
-0.0189
-3.7282
-7.4374


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000


Axial Stress (ksi)
0.3125
0.2014
0.0904
-0.0207
-0.1317
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	0.0074	1.8583	0.0361	0.0269	-0.0045	-0.0198
ULS: 2. D + L	0.0074	1.8583	0.0361	0.0269	-0.0045	-0.0198
ULS: 3. D + (S or Lr or R)	0.0190	4.1264	0.0924	0.0693	-0.0122	-0.0859
ULS: 3. D + (S or Lr or R)	0.0074	1.8583	0.0361	0.0269	-0.0045	-0.0198
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0161	3.5594	0.0783	0.0587	-0.0103	-0.0694
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	1.8583	0.0361	0.0269	-0.0045	-0.0198
ULS: 5b. D + 0.7E	0.0074	1.8583	0.0361	0.0269	-0.0045	-0.0198
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0161	3.5594	0.0783	0.0587	-0.0103	-0.0694
ULS: 8. 0.6D + 0.7E	0.0044	1.1150	0.0216	0.0161	-0.0027	-0.0119
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9844	5.3016	0.1253	0.0607	-0.2242	12.9478
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9844	5.3016	0.1253	0.0607	-0.2242	12.9478
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7146	-1.0931	-0.0399	-0.0021	0.1829	-11.0211
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4344	-0.6036	-0.0327	0.0014	0.1690	-16.3534
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4778	6.1419	0.1453	0.0841	-0.1751	9.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4778	6.1419	0.1453	0.0841	-0.1751	9.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2965	1.3458	0.0214	0.0370	0.1303	-8.3204
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0864	1.7129	0.0268	0.0396	0.1198	-12.3196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4865	4.4408	0.1030	0.0523	-0.1693	9.7059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4865	4.4408	0.1030	0.0523	-0.1693	9.7059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2878	-0.3553	-0.0209	0.0051	0.1360	-8.2708
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0777	0.0118	-0.0155	0.0078	0.1256	-12.2700
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9874	4.5583	0.1109	0.0500	-0.2224	12.9557
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9874	4.5583	0.1109	0.0500	-0.2224	12.9557
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7116	-1.8364	-0.0543	-0.0129	0.1847	-11.0132
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4315	-1.3470	-0.0471	-0.0093	0.1708	-16.3455

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.1029
Shear X	-3.3197
Shear Z	0.2208
Moment X	0.1297
Moment Y (Twist)	0.3758
Moment Z	27.4002

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.1419
Shear X	-1.9874
Shear Z	0.1453
Moment X	0.0841
Moment Y (Twist)	0.2242
Moment Z	16.3534

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	-0.0081	2.0878	-0.0030	-0.0036	0.0063	0.0752
ULS: 2. D + L	-0.0081	2.0878	-0.0030	-0.0036	0.0063	0.0752
ULS: 3. D + (S or Lr or R)	-0.0207	4.7124	-0.0077	-0.0091	0.0163	0.1585
ULS: 3. D + (S or Lr or R)	-0.0081	2.0878	-0.0030	-0.0036	0.0063	0.0752
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0175	4.0563	-0.0065	-0.0077	0.0138	0.1377
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0081	2.0878	-0.0030	-0.0036	0.0063	0.0752
ULS: 5b. D + 0.7E	-0.0081	2.0878	-0.0030	-0.0036	0.0063	0.0752

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0175	4.0563	-0.0065	-0.0077	0.0138	0.1377
ULS: 8. 0.6D + 0.7E	-0.0048	1.2527	-0.0018	-0.0022	0.0038	0.0451
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3162	6.0924	-0.0101	-0.0135	0.0145	15.0314
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3162	6.0924	-0.0101	-0.0135	0.0145	15.0314
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9704	-1.3447	0.0031	0.0049	-0.0009	-12.5957
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6357	-0.7686	-0.0006	0.0031	0.0112	-18.5600
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7486	7.0597	-0.0119	-0.0152	0.0199	11.3548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7486	7.0597	-0.0119	-0.0152	0.0199	11.3548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4663	1.4819	-0.0019	-0.0014	0.0084	-9.3655
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2153	1.9140	-0.0047	-0.0027	0.0174	-13.8387
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7392	5.0912	-0.0084	-0.0110	0.0125	11.2923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7392	5.0912	-0.0084	-0.0110	0.0125	11.2923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4758	-0.4866	0.0016	0.0028	0.0009	-9.4280
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2247	-0.0545	-0.0012	0.0014	0.0099	-13.9012
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3130	5.2572	-0.0089	-0.0121	0.0120	15.0013
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3130	5.2572	-0.0089	-0.0121	0.0120	15.0013
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9737	-2.1799	0.0043	0.0063	-0.0034	-12.6258
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6389	-1.6037	0.0006	0.0045	0.0086	-18.5901

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.4919
Shear X	-3.8628
Shear Z	-0.0178
Moment X	-0.0236
Moment Y (Twist)	0.0303
Moment Z	31.0805

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.0597
Shear X	-2.3162
Shear Z	-0.0119
Moment X	-0.0152
Moment Y (Twist)	0.0199
Moment Z	18.5901

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	0.0013	2.0707	0.0000	0.0000	0.0000	0.0220
ULS: 2. D + L	0.0013	2.0707	0.0000	0.0000	0.0000	0.0220
ULS: 3. D + (S or Lr or R)	0.0034	4.6684	0.0000	-0.0000	0.0000	0.0220
ULS: 3. D + (S or Lr or R)	0.0013	2.0707	0.0000	0.0000	0.0000	0.0220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0029	4.0190	0.0000	-0.0000	0.0000	0.0220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0013	2.0707	0.0000	0.0000	0.0000	0.0220
ULS: 5b. D + 0.7E	0.0013	2.0707	0.0000	0.0000	0.0000	0.0220
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0029	4.0190	0.0000	-0.0000	0.0000	0.0220
ULS: 8. 0.6D + 0.7E	0.0008	1.2424	0.0000	0.0000	0.0000	0.0132
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2828	6.0266	0.0000	0.0000	0.0000	14.8930
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.2828	6.0266	0.0000	0.0000	0.0000	14.8930
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9591	-1.3200	0.0000	0.0000	0.0000	-12.5758
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6341	-0.7581	0.0000	0.0000	0.0000	-18.6576
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7102	6.9859	0.0000	-0.0000	0.0000	11.1753
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7102	6.9859	0.0000	-0.0000	0.0000	11.1753
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4712	1.4760	0.0000	-0.0000	0.0000	-9.4263
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2275	1.8974	0.0000	-0.0000	0.0000	-13.9877

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7118	5.0376	0.0000	0.0000	0.0000	11.1753
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7118	5.0376	0.0000	0.0000	0.0000	11.1753
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4697	-0.4724	0.0000	0.0000	0.0000	-9.4264
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2259	-0.0509	0.0000	0.0000	0.0000	-13.9877
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2834	5.1983	0.0000	0.0000	0.0000	14.8843
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.2834	5.1983	0.0000	0.0000	0.0000	14.8843
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9586	-2.1483	0.0000	0.0000	0.0000	-12.5846
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6336	-1.5864	0.0000	0.0000	0.0000	-18.6664

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.3770
Shear X	-3.8069
Shear Z	0.0000
Moment X	0.0001
Moment Y (Twist)	0.0002
Moment Z	31.2616

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.9859
Shear X	-2.2834
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	18.6664

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	-0.0081	2.0878	0.0030	0.0036	-0.0063	0.0752
ULS: 2. D + L	-0.0081	2.0878	0.0030	0.0036	-0.0063	0.0752
ULS: 3. D + (S or Lr or R)	-0.0207	4.7124	0.0077	0.0091	-0.0162	0.1585
ULS: 3. D + (S or Lr or R)	-0.0081	2.0878	0.0030	0.0036	-0.0063	0.0752
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0175	4.0563	0.0065	0.0077	-0.0137	0.1377
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0081	2.0878	0.0030	0.0036	-0.0063	0.0752
ULS: 5b. D + 0.7E	-0.0081	2.0878	0.0030	0.0036	-0.0063	0.0752
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0175	4.0563	0.0065	0.0077	-0.0137	0.1377
ULS: 8. 0.6D + 0.7E	-0.0048	1.2527	0.0018	0.0022	-0.0038	0.0451
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3162	6.0924	0.0101	0.0135	-0.0145	15.0314
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3162	6.0924	0.0101	0.0135	-0.0145	15.0314
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9704	-1.3447	-0.0031	-0.0049	0.0009	-12.5957
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6357	-0.7686	0.0006	-0.0031	-0.0111	-18.5600
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7486	7.0597	0.0119	0.0152	-0.0199	11.3548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7486	7.0597	0.0119	0.0152	-0.0199	11.3548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4663	1.4819	0.0019	0.0014	-0.0083	-9.3655
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2153	1.9140	0.0047	0.0027	-0.0174	-13.8387
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7392	5.0912	0.0084	0.0110	-0.0124	11.2923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7392	5.0912	0.0084	0.0110	-0.0124	11.2923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4758	-0.4866	-0.0016	-0.0028	-0.0009	-9.4280
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2247	-0.0545	0.0012	-0.0014	-0.0099	-13.9012
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3130	5.2572	0.0089	0.0121	-0.0120	15.0013
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3130	5.2572	0.0089	0.0121	-0.0120	15.0013
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9737	-2.1799	-0.0043	-0.0063	0.0034	-12.6258
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6389	-1.6037	-0.0006	-0.0045	-0.0086	-18.5901

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.4919
Shear X	-3.8628
Shear Z	0.0178
Moment X	0.0238
Moment Y (Twist)	0.0299
Moment Z	31.0804

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

Result	Value (kip, kip-ft)
Axial	7.0597
Shear X	-2.3162
Shear Z	0.0119
Moment X	0.0152
Moment Y (Twist)	0.0199
Moment Z	18.5901

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0074	1.8583	-0.0361	-0.0269	0.0046	-0.0198
ULS: 2. D + L	0.0074	1.8583	-0.0361	-0.0269	0.0046	-0.0198
ULS: 3. D + (S or Lr or R)	0.0190	4.1264	-0.0924	-0.0694	0.0123	-0.0859
ULS: 3. D + (S or Lr or R)	0.0074	1.8583	-0.0361	-0.0269	0.0046	-0.0198
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0161	3.5594	-0.0783	-0.0588	0.0104	-0.0694
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	1.8583	-0.0361	-0.0269	0.0046	-0.0198
ULS: 5b. D + 0.7E	0.0074	1.8583	-0.0361	-0.0269	0.0046	-0.0198
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0161	3.5594	-0.0783	-0.0588	0.0104	-0.0694
ULS: 8. 0.6D + 0.7E	0.0044	1.1150	-0.0216	-0.0161	0.0027	-0.0119
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9844	5.3016	-0.1253	-0.0608	0.2242	12.9478
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9844	5.3016	-0.1253	-0.0608	0.2242	12.9478
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7146	-1.0931	0.0399	0.0021	-0.1829	-11.0211
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4344	-0.6036	0.0327	-0.0014	-0.1690	-16.3534
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4778	6.1419	-0.1453	-0.0842	0.1751	9.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4778	6.1419	-0.1453	-0.0842	0.1751	9.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2965	1.3458	-0.0214	-0.0370	-0.1302	-8.3204
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0864	1.7129	-0.0268	-0.0397	-0.1198	-12.3196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4865	4.4408	-0.1030	-0.0523	0.1693	9.7059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4865	4.4408	-0.1030	-0.0523	0.1693	9.7059
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2878	-0.3553	0.0209	-0.0051	-0.1360	-8.2708
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0777	0.0118	0.0155	-0.0078	-0.1256	-12.2700
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9874	4.5583	-0.1109	-0.0500	0.2224	12.9557
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9874	4.5583	-0.1109	-0.0500	0.2224	12.9557
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7116	-1.8364	0.0543	0.0129	-0.1847	-11.0132
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4315	-1.3470	0.0471	0.0093	-0.1708	-16.3455

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.1029
Shear X	-3.3197
Shear Z	-0.2207
Moment X	-0.1297
Moment Y (Twist)	0.3761
Moment Z	27.4006

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.1419
Shear X	-1.9874
Shear Z	-0.1453
Moment X	-0.0842
Moment Y (Twist)	0.2242
Moment Z	16.3534

Project Details

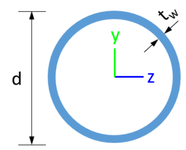
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

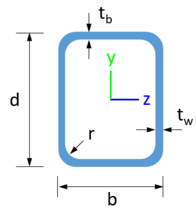
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

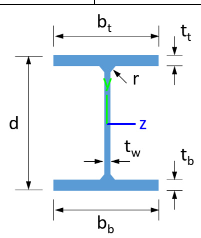
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
9	8in Pipe Sch 40	8.63	0.32					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	13.56	13.56	6.46	-	300	200	1
2	5	4.20	4.20	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.20,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,2.20,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.59	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.70,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	1.72,1.72,1.72,1.72,1.72,1.72,1.71,1.71,1.69,2.12,1.70,1.70,1.69,1.05,1.71,1.71,1.76,1.80,1.71,1.71,1.68,2.07,1.70,1.70,1.70,1.22	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.16,1.67,1.67,1.68,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.61	300	200	1
11	19	1.33	1.33	2.05	1.74,1.74,1.74,1.74,1.74,1.74,1.75,1.75,1.77,1.88,1.75,1.75,1.77,1.85,1.75,1.75,1.71,1.43,1.75,1.75,1.78,1.90,1.76,1.76,1.76,1.85	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.06,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12	300	200	1
14	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.61,1.11,1.11,1.11,1.18,1.11,1.11,1.10,1.12,1.11,1.11,1.11,1.28,1.11,1.11,1.11,1.08	300	200	1
15	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	13.56	13.56	6.46	-	300	200	1
102	5	4.20	4.20	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.39,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.62	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1

108	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.05,2.09,2.09,2.09,1.43,2.09,2.09,2.09,2.08,2.09,2.09,2.09,2.06,2.09,2.09,2.09,2.31	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.20,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.62	300	200	1
111	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.08,2.07,2.08,2.08,2.08,2.08,2.09,2.09,2.10,2.34,2.08,2.08,2.08,2.07,2.08,2.08,2.08,2.08	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.06,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.07,1.04,1.04,1.04,1.05	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.96,1.04,1.04,1.04,1.01,1.04,1.04,1.04,1.04,1.04,1.04,1.36,1.04,1.04,1.04,1.02	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.14,1.15,1.15,1.16,1.22,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.14	300	200	1
116	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.11,1.16,1.16,1.16,1.99,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.13,1.16,1.16,1.16,1.29	300	200	1
201	9	13.56	13.56	6.46	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.16,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.61	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.29,2.08,2.08,2.08,1.03,2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.11,2.08,2.08,2.08,1.62	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.69,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.16,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.61	300	200	1
211	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.09,2.08,2.08,2.09,2.06,2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.09	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.53,1.04,1.04,1.04,1.01,1.04,1.04,1.04,1.04,1.04,1.04,1.25,1.04,1.04,1.04,1.02	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
216	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.18,1.15,1.15,1.15,1.24,1.15,1.15,1.15,1.16,1.15,1.15,1.16,1.17,1.15,1.15,1.15,1.12	300	200	1
301	9	13.56	13.56	6.46	-	300	200	1

302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.20,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.62	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
308	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,1.63,2.08,2.08,2.08,1.29,2.08,2.08,2.07,2.07,2.08,2.08,2.08,1.80,2.08,2.08,2.08,2.12	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.38,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.62	300	200	1
311	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.07,2.06,1.99,2.07,2.07,2.06,2.03,2.07,2.07,2.09,2.27,2.07,2.07,2.06,1.96,2.07,2.07,2.07,2.05	300	200	1
312	5	4.20	4.20	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.06,1.04,1.04,1.05,1.05,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.07,1.04,1.04,1.04,1.05	300	200	1
314	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.96,1.04,1.04,1.04,1.01,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.36,1.04,1.04,1.04,1.02	300	200	1
315	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.19,1.16,1.16,1.15,1.15,1.16,1.16,1.15,1.15	300	200	1
316	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.16,1.16,1.70,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.16,1.16,1.20	300	200	1
401	9	13.56	13.56	6.46	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.17,1.67,1.67,1.68,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.61	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
406	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.20,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
407	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.70,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
408	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,2.19,1.67,1.67,1.69,1.68,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.59	300	200	1
411	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	5	4.20	4.20	2.00	-	00	00	1
413	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.07,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12	300	200	1
414	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.61,1.11,1.11,1.11,1.18,1.11,1.11,1.10,1.12,1.11,1.11,1.11,1.28,1.11,1.11,1.11,1.08	300	200	1
415	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.12,1.12,1.13,1.13,1.12,1.12,1.12,1.11,1.12,1.12,1.13,1.14,1.12,1.12,1.13,1.13	300	200	1
416	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.17,1.12,1.12,1.12,1.70,1.12,1.12,1.12,1.13,1.12,1.12,1.12,1.15,1.12,1.12,1.12,1.10	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	377.97	301.99	83.29	83.29	113.39	113.39
2	198.33	182.14	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	24.29	6.12	40.24	43.62
14	133.20	104.94	24.75	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	377.97	301.99	83.29	83.29	113.39	113.39
102	198.33	182.14	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.60	6.12	40.24	43.62
114	133.20	104.94	23.14	6.12	40.24	43.62
115	133.20	69.16	17.64	6.12	40.24	43.62
116	133.20	69.16	17.18	6.12	40.24	43.62
201	377.97	301.99	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28

208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	23.60	6.12	40.24	43.62
214	133.20	104.94	23.14	6.12	40.24	43.62
215	133.20	69.16	17.64	6.12	40.24	43.62
216	133.20	69.16	17.33	6.12	40.24	43.62
301	377.97	301.99	83.29	83.29	113.39	113.39
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	126.01	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	126.01	32.87	6.12	40.24	43.62
312	198.33	182.14	21.95	21.95	59.50	59.50
313	133.20	104.94	23.60	6.12	40.24	43.62
314	133.20	104.94	23.14	6.12	40.24	43.62
315	133.20	69.16	17.80	6.12	40.24	43.62
316	133.20	69.16	17.64	6.12	40.24	43.62
401	377.97	301.99	83.29	83.29	113.39	113.39
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	52.83	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	52.83	32.87	6.12	40.24	43.62
412	198.33	182.14	21.95	21.95	59.50	59.50
413	133.20	104.94	24.52	6.12	40.24	43.62
414	133.20	104.94	24.75	6.12	40.24	43.62
415	133.20	69.16	17.18	6.12	40.24	43.62
416	133.20	69.16	17.02	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.030	0.329	0.016	0.029	0.002	0.331	#32	0.277	Not Required	Pass
2	0.002	0.318	0.142	0.070	0.027	0.461	#13	0.114	Not Required	Pass
3	0.006	0.518	0.025	0.052	0.002	0.528	#13	0.045	Not Required	Pass
4	0.005	0.517	0.086	0.052	0.019	0.559	#13	0.080	Not Required	Pass
5	0.005	0.321	0.080	0.052	0.020	0.328	#13	0.074	Not Required	Pass
6	0.007	0.579	0.055	0.059	0.011	0.615	#13	0.045	Not Required	Pass
7	0.007	0.359	0.114	0.058	0.029	0.378	#13	0.074	Not Required	Pass
8	0.001	0.071	0.098	0.039	0.011	0.104	#24	0.095	Not Required	Pass

9	0.007	0.054	0.048	0.001	0.002	0.101	#13	0.204	Not Required	Pass
10	0.007	0.573	0.106	0.058	0.022	0.601	#13	0.080	Not Required	Pass
11	0.002	0.069	0.100	0.039	0.011	0.109	#21	0.095	Not Required	Pass
12	0.001	0.378	0.159	0.079	0.029	0.537	#13	0.053	Not Required	Pass
13	0.003	0.177	0.257	0.051	0.014	0.378	#21	0.286	Not Required	Pass
14	0.004	0.178	0.255	0.050	0.014	0.369	#21	0.190	Not Required	Pass
15	0.000	0.057	0.090	0.025	0.007	0.139	#21	Not Required	Not Required	Pass
16	0.000	0.057	0.090	0.025	0.007	0.139	#21	Not Required	Not Required	Pass
101	0.035	0.373	0.001	0.034	0.000	0.377	#32	0.277	Not Required	Pass
102	0.002	0.405	0.177	0.087	0.033	0.582	#13	0.114	Not Required	Pass
103	0.007	0.636	0.043	0.064	0.006	0.663	#13	0.045	Not Required	Pass
104	0.007	0.638	0.107	0.064	0.023	0.679	#13	0.080	Not Required	Pass
105	0.007	0.394	0.111	0.064	0.028	0.410	#13	0.074	Not Required	Pass
106	0.007	0.633	0.042	0.064	0.006	0.658	#13	0.045	Not Required	Pass
107	0.007	0.393	0.110	0.063	0.028	0.408	#13	0.074	Not Required	Pass
108	0.001	0.049	0.097	0.041	0.011	0.128	#21	0.095	Not Required	Pass
109	0.009	0.057	0.037	0.001	0.000	0.097	#13	0.204	Not Required	Pass
110	0.007	0.632	0.107	0.064	0.023	0.674	#13	0.080	Not Required	Pass
111	0.002	0.050	0.098	0.040	0.011	0.130	#21	0.095	Not Required	Pass
112	0.002	0.401	0.175	0.086	0.032	0.576	#13	0.035	Not Required	Pass
113	0.003	0.201	0.257	0.053	0.014	0.417	#21	0.286	Not Required	Pass
114	0.005	0.209	0.256	0.053	0.014	0.418	#21	0.286	Not Required	Pass
115	0.003	0.242	0.142	0.042	0.011	0.354	#21	0.473	Not Required	Pass
116	0.001	0.240	0.143	0.042	0.011	0.352	#21	0.473	Not Required	Pass
201	0.034	0.375	0.000	0.034	0.000	0.378	#32	0.277	Not Required	Pass
202	0.002	0.398	0.174	0.085	0.032	0.572	#13	0.035	Not Required	Pass
203	0.007	0.629	0.042	0.063	0.006	0.655	#13	0.045	Not Required	Pass
204	0.007	0.625	0.106	0.063	0.023	0.666	#13	0.080	Not Required	Pass
205	0.007	0.390	0.110	0.063	0.028	0.405	#13	0.074	Not Required	Pass
206	0.007	0.629	0.042	0.063	0.006	0.655	#13	0.045	Not Required	Pass
207	0.007	0.390	0.110	0.063	0.028	0.405	#13	0.074	Not Required	Pass
208	0.001	0.051	0.096	0.040	0.011	0.125	#21	0.095	Not Required	Pass
209	0.008	0.057	0.036	0.001	0.000	0.095	#13	0.204	Not Required	Pass
210	0.007	0.625	0.106	0.063	0.023	0.666	#13	0.080	Not Required	Pass
211	0.002	0.051	0.098	0.040	0.011	0.129	#21	0.095	Not Required	Pass
212	0.002	0.398	0.174	0.085	0.032	0.572	#13	0.035	Not Required	Pass
213	0.003	0.201	0.255	0.052	0.014	0.416	#21	0.286	Not Required	Pass
214	0.005	0.204	0.253	0.052	0.014	0.411	#21	0.286	Not Required	Pass
215	0.003	0.215	0.142	0.040	0.011	0.331	#21	0.473	Not Required	Pass
216	0.001	0.215	0.143	0.040	0.011	0.331	#21	0.473	Not Required	Pass
301	0.035	0.373	0.001	0.034	0.000	0.377	#32	0.277	Not Required	Pass
302	0.002	0.401	0.175	0.086	0.032	0.576	#13	0.035	Not Required	Pass
303	0.007	0.633	0.042	0.064	0.006	0.658	#13	0.045	Not Required	Pass
304	0.007	0.632	0.107	0.064	0.023	0.674	#13	0.080	Not Required	Pass
305	0.007	0.393	0.110	0.063	0.028	0.408	#13	0.074	Not Required	Pass
306	0.007	0.636	0.043	0.064	0.006	0.663	#13	0.045	Not Required	Pass
307	0.007	0.394	0.112	0.064	0.028	0.410	#13	0.074	Not Required	Pass
308	0.001	0.056	0.099	0.042	0.011	0.127	#21	0.095	Not Required	Pass
309	0.009	0.057	0.037	0.001	0.000	0.097	#13	0.204	Not Required	Pass
310	0.007	0.638	0.107	0.064	0.023	0.679	#13	0.080	Not Required	Pass
311	0.002	0.058	0.100	0.042	0.011	0.127	#21	0.095	Not Required	Pass
312	0.002	0.405	0.177	0.087	0.033	0.582	#13	0.114	Not Required	Pass
313	0.003	0.201	0.257	0.053	0.014	0.417	#21	0.286	Not Required	Pass
314	0.005	0.209	0.256	0.053	0.014	0.418	#21	0.286	Not Required	Pass

315	0.003	0.215	0.142	0.040	0.011	0.331	#21	0.473	Not Required	Pass
316	0.001	0.214	0.143	0.041	0.011	0.329	#21	0.473	Not Required	Pass
401	0.030	0.329	0.016	0.029	0.002	0.331	#32	0.277	Not Required	Pass
402	0.001	0.378	0.159	0.079	0.029	0.537	#13	0.053	Not Required	Pass
403	0.007	0.579	0.055	0.059	0.011	0.615	#13	0.045	Not Required	Pass
404	0.007	0.573	0.106	0.058	0.022	0.601	#13	0.080	Not Required	Pass
405	0.007	0.359	0.114	0.058	0.029	0.378	#13	0.074	Not Required	Pass
406	0.006	0.518	0.025	0.052	0.002	0.528	#13	0.045	Not Required	Pass
407	0.005	0.321	0.080	0.052	0.020	0.328	#13	0.074	Not Required	Pass
408	0.000	0.057	0.090	0.025	0.007	0.139	#21	Not Required	Not Required	Pass
409	0.007	0.054	0.048	0.001	0.002	0.101	#13	0.204	Not Required	Pass
410	0.005	0.517	0.086	0.052	0.019	0.559	#13	0.080	Not Required	Pass
411	0.000	0.057	0.090	0.025	0.007	0.139	#21	Not Required	Not Required	Pass
412	0.002	0.318	0.142	0.070	0.027	0.461	#13	0.114	Not Required	Pass
413	0.003	0.177	0.257	0.051	0.014	0.378	#21	0.190	Not Required	Pass
414	0.004	0.178	0.255	0.050	0.014	0.369	#21	0.286	Not Required	Pass
415	0.003	0.247	0.142	0.039	0.011	0.358	#21	0.473	Not Required	Pass
416	0.001	0.246	0.143	0.039	0.011	0.358	#21	0.473	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/comresssion)
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

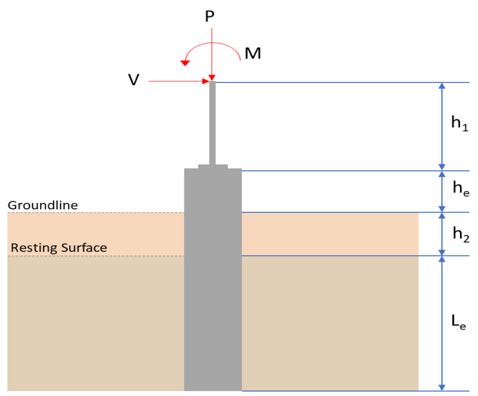
SkyCiv Foundation Design

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
$L = 7.5\ \mathrm{ft}$ - 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)	6.142	9.103
V_x (kip)	-1.987	-3.320
V_z (kip)	0.145	0.221
M_x (kipft)	0.084	0.130
M_z (kipft)	16.353	27.400

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.987\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.66233\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.353 \text{ kipft}) + ((-1.987 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.451 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.524 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.145 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.048333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.084 \text{ kipft}) + ((0.145 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.028 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.4481 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.524 \text{ ft}), (2.4481 \text{ ft})]$$

$$L_{e,req} = 6.524 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.524 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.86987$$

Status: **PASS**
Ratio: **0.870**

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

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

$$q = \frac{(6.142 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.86892 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.86892 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.43446$$

Status: **PASS**
Ratio: **0.430**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66233 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 5.451 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.451 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.66233 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (5.451 \text{ kipft/ft})) + (4 \times (-0.66233 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.2362 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.451 \text{ kipft/ft})) + (3 \times (-0.66233 \text{ kip/ft}) \times (7.5 \text{ ft}))]^{\,2}}{(7.5 \text{ ft})^2 \times [(3 \times (5.451 \text{ kipft/ft})) + (2 \times (-0.66233 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.15542 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.451 \text{ kipft/ft})) + ((-0.66233 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 0.99436 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2362 \text{ ft})}{2}$$

$$p_a = 0.39272 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.15542 \text{ kip/ft}^2\right)}{\left(0.39272 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.39576$$

Status: **PASS**
Ratio: **0.400**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.99436\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88387$$

Status: **PASS**
Ratio: **0.880**

Considering z-direction:

$H_o = 0.048333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.028\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.028\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.028\ \mathrm{kipft/ft})) + (4 \times (0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.5601\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.028\ \mathrm{kipft/ft})) + (3 \times (0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.028\ \mathrm{kipft/ft})) + (2 \times (0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.037246\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.028\ \mathrm{kipft/ft})) + ((0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.070122\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5601\ \mathrm{ft})}{2}$$

$$p_a = 0.41701\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.037246\ \mathrm{kip/ft^2}\right)}{\left(0.41701\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.089316$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

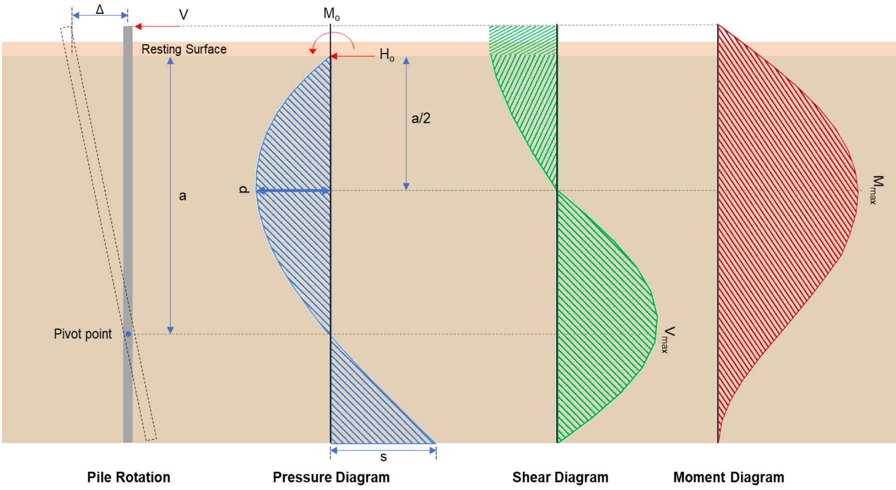
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.070122 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.062331$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.32 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1067 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.4 \text{ kipft}) + ((-3.32 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.1333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.1333 \text{ kipft/ft})}{(-1.1067 \text{ kip/ft})}$$

$$E = 8.253 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1333 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-1.1067 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (9.1333 \text{ kipft/ft})) + (4 \times (-1.1067 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.2358 \text{ ft}$$

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

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

$$V_{max} = ((-1.1067 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.253 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.2358 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.253 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.2358 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.6559 \text{ kip}$$

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

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

$$M_{max} = ((-1.1067 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.253 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.253 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.253 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 30.213 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.221 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.073667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.13 \text{ kipft}) + ((0.221 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.043333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.043333 \text{ kipft/ft})}{(0.073667 \text{ kip/ft})}$$

$$E = 0.58824 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.043333 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (0.073667 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.043333 \text{ kipft/ft})) + (4 \times (0.073667 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.5592 \text{ ft}$$

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

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

$$V_{max} = ((0.073667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.5592 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.5592 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.18136 \text{ kip}$$

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

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

$$M_{max} = ((0.073667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(0.58824 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.53459 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.103 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.089 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.089 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(9.103\text{ kip})}{(1253.9\text{ kip})}$$ $$Ratio = 0.0072597$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\text{ in})$$ $$d = 28.8\text{ in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,max} = 186.09\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 9.103\text{ kip} \rightarrow 9103\text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(9103\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,a} = 75.983\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,b} = 204.04\text{ kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\text{ kip}), (75.983\text{ kip}), (204.04\text{ kip})\right]$$	

$$V_c = 75.983\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.983\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.2\ \text{kip}$$

Considering x-direction:

$V_{max} = 8.6559\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.6559\ \text{kip})}{(74.2\ \text{kip})}$$

$$Ratio = 0.11666$$

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

Considering z-direction:

$V_{max} = 0.18136\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.18136\ \text{kip})}{(74.2\ \text{kip})}$$

$$Ratio = 0.0024442$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 30.213\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(30.213\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.4871$$

Status: **PASS**
Ratio: **0.490**

Considering z-direction:

$M_{max} = 0.53459\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.53459\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.0086187$$

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

REFERENCES	CALCULATIONS	RESULTS

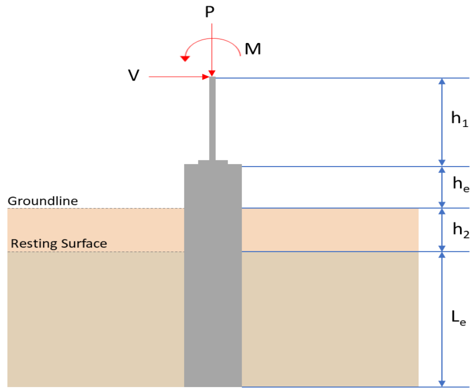
SkyCiv Foundation Design

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
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.060	10.492
V_x (kip)	-2.316	-3.863
V_z (kip)	-0.012	-0.018
M_x (kipft)	-0.015	-0.024
M_z (kipft)	18.590	31.080

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.316\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.772\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.59 \text{ kipft}) + ((-2.316 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 6.1967 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.6534 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.012 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.004 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.015 \text{ kipft}) + ((-0.012 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.005 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.71143 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6534 \text{ ft}), (0.71143 \text{ ft})]$$

$$L_{e,req} = 6.653 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.653 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.88707$$

Status: **PASS**
Ratio: **0.890**

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

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

$$q = \frac{(7.06 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.9988\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.9988\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.4994$$

Status: **PASS**
Ratio: **0.500**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.772\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.1967\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.1967\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.1967\ \mathrm{kipft/ft})) + (4 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2399\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.1967\ \mathrm{kipft/ft})) + (3 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.1967\ \mathrm{kipft/ft})) + (2 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.16433\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (6.1967\ \mathrm{kipft/ft})) + ((-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.1064\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2399\ \mathrm{ft})}{2}$$

$$p_a = 0.393\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.16433\ \mathrm{kip/ft^2})}{(0.393\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.41816$$

Status: **PASS**
Ratio: **0.420**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1064 \text{ kip/ft}^2\right)}{\left(1.125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.98349$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = -0.004 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.005 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.004 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.005 \text{ kipft/ft})) + (4 \times (-0.004 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

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

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

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

$$p = \frac{1.178 \times [(4 \times (0.005 \text{ kipft/ft})) + (3 \times (-0.004 \text{ kip/ft}) \times (7.5 \text{ ft}))]^{\,2}}{(7.5 \text{ ft})^2 \times [(3 \times (0.005 \text{ kipft/ft})) + (2 \times (-0.004 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = -0.0022804 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.005 \text{ kipft/ft})) + ((-0.004 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = -0.0033511 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5 \text{ ft})}{2}$$

$$p_a = 0.4125 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0022804 \text{ kip/ft}^2\right)}{\left(0.4125 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.0055282$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

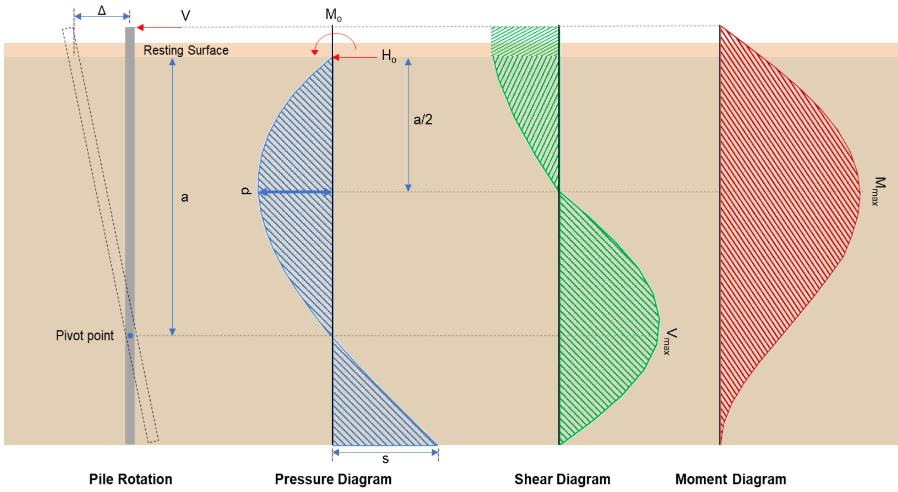
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0033511\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0029788$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.863\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.2877\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.08\ \mathrm{kipft}) + ((-3.863\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 10.36\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.36\ \mathrm{kipft/ft})}{(-1.2877\ \mathrm{kip/ft})}$$

$$E = 8.0456\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.36\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-1.2877\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (10.36\ \mathrm{kipft/ft})) + (4 \times (-1.2877\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2395\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.2877\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.0456\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2395\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.0456\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2395\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8829 \text{ kip}$$

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

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

$$M_{max} = ((-1.2877 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.0456 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.0456 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.0456 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 34.448 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.006 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.024 \text{ kipft}) + ((-0.018 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.008 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.008 \text{ kipft/ft})}{(-0.006 \text{ kip/ft})}$$

$$E = 1.3333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.008 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.006 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.008 \text{ kipft/ft})) + (4 \times (-0.006 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.4934 \text{ ft}$$

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

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

$$V_{max} = ((-0.006 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4934 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4934 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.017838 \text{ kip}$$

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

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

$$M_{max} = ((-0.006 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(1.3333 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.054984 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.492 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.045 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.045 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.492\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0083674$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.492\ \text{kip} \rightarrow 10492\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(10492\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.219\ \text{kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.219\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.219\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.219\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.353\ \text{kip}$$

Considering x-direction:

$V_{max} = 9.8829\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.8829\ \text{kip})}{(74.353\ \text{kip})}$$

$$Ratio = 0.13292$$

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

Considering z-direction:

$V_{max} = 0.017838\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.017838\ \text{kip})}{(74.353\ \text{kip})}$$

$$Ratio = 0.0002399$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 34.448 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(34.448 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.55537$$

Status: **PASS**
Ratio: **0.560**

Considering z-direction:

$M_{max} = 0.054984 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.054984 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.00088646$$

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

REFERENCES	CALCULATIONS	RESULTS

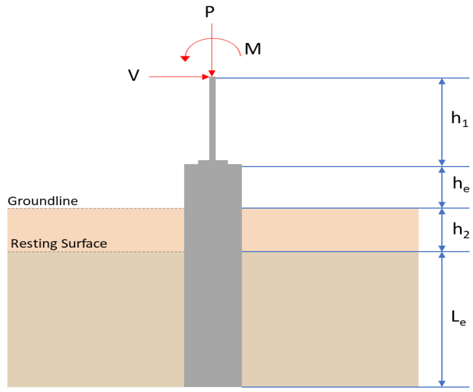
SkyCiv Foundation Design

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
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.060	10.492
V_x (kip)	-2.316	-3.863
V_z (kip)	0.012	0.018
M_x (kipft)	0.015	0.024
M_z (kipft)	18.590	31.080

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.316\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.772\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(18.59\ \text{kipft}) + ((-2.316\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 6.1967\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.6534\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.012\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.004\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.015\ \text{kipft}) + ((0.012\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.005\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.0021\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6534\ \text{ft}), (1.0021\ \text{ft})]$$

$$L_{e,req} = 6.653\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.653\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.88707$$

Status: **PASS**
Ratio: **0.890**

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

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

$$q = \frac{(7.06\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.9988\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.9988\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.4994$$

Status: **PASS**
Ratio: **0.500**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.772\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.1967\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.1967\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.1967\ \mathrm{kipft/ft})) + (4 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2399\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.1967\ \mathrm{kipft/ft})) + (3 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.1967\ \mathrm{kipft/ft})) + (2 \times (-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.16433\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (6.1967\ \mathrm{kipft/ft})) + ((-0.772\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.1064\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2399\ \mathrm{ft})}{2}$$

$$p_a = 0.393\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.16433\ \mathrm{kip/ft^2}\right)}{\left(0.393\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.41816$$

Status: **PASS**
Ratio: **0.420**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1064\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.98349$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.004\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.005\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.004\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.005\ \mathrm{kipft/ft})) + (4 \times (0.004\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.5\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.005\ \mathrm{kipft/ft})) + (3 \times (0.004\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.005\ \mathrm{kipft/ft})) + (2 \times (0.004\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0033787\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.005\ \mathrm{kipft/ft})) + ((0.004\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.0067022\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5\ \mathrm{ft})}{2}$$

$$p_a = 0.4125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0033787\ \mathrm{kip/ft^2}\right)}{\left(0.4125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0081907$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

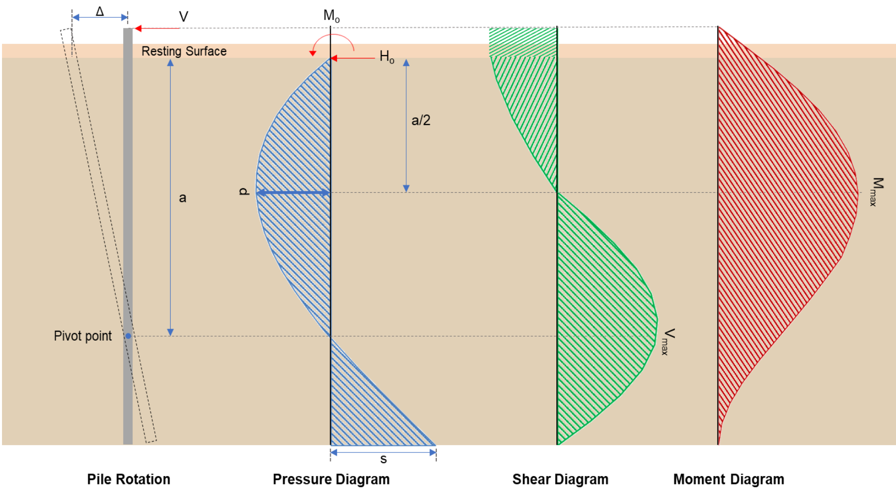
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.0067022\ \text{kip/ft}^2)}{(1.125\ \text{kip/ft}^2)}$$

$$Ratio = 0.0059575$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.863\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -1.2877\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.08\ \text{kipft}) + ((-3.863\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 10.36\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.36\ \text{kipft/ft})}{(-1.2877\ \text{kip/ft})}$$

$$E = 8.0456\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.36\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-1.2877\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (10.36\ \text{kipft/ft})) + (4 \times (-1.2877\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.2395\ \text{ft}$$

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

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

$$V_{max} = ((-1.2877\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.0456\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.2395\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.0456\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.2395\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8829 \text{ kip}$$

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

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

$$M_{max} = ((-1.2877 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.0456 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.0456 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.0456 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.2395 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 34.448 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.018 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.006 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.024 \text{ kipft}) + ((0.018 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.008 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.008 \text{ kipft/ft})}{(0.006 \text{ kip/ft})}$$

$$E = 1.3333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.008 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (0.006 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.008 \text{ kipft/ft})) + (4 \times (0.006 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.4934 \text{ ft}$$

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

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

$$V_{max} = ((0.006 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4934 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4934 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.017838 \text{ kip}$$

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

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

$$M_{max} = ((0.006 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(1.3333 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (1.3333 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.4934 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.054984 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.492 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.045 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.045 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.492 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.0083674$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.492 \text{ kip} \rightarrow 10492 \text{ lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(10492 \text{ lbf})}{6 \times \left(1017.9 \text{ in}^2\right)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.219 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.219 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.219 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.219 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.353 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.8829 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.8829 \text{ kip})}{(74.353 \text{ kip})}$$

$$Ratio = 0.13292$$

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

Considering z-direction:

$V_{max} = 0.017838 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.017838 \text{ kip})}{(74.353 \text{ kip})}$$

$$Ratio = 0.0002399$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 34.448\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(34.448\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.55537$$	Status: **PASS** Ratio: **0.560**
	Considering z-direction: $M_{max} = 0.054984\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.054984\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.00088646$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

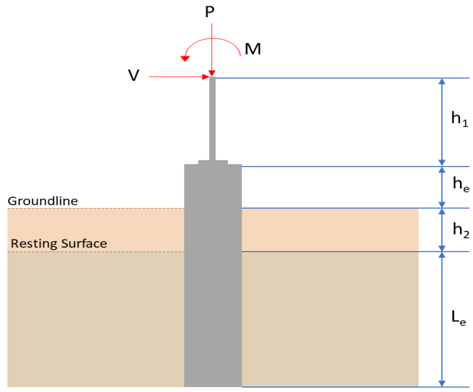
SkyCiv Foundation Design

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
$L = 7.5\ \mathrm{ft}$ - 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)	6.142	9.103
V_x (kip)	-1.987	-3.320
V_z (kip)	-0.145	-0.221
M_x (kipft)	-0.084	-0.130
M_z (kipft)	16.353	27.401

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.987\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.66233\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.353 \text{ kipft}) + ((-1.987 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.451 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.524 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.145 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.048333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.084 \text{ kipft}) + ((-0.145 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.028 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.69776 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.524 \text{ ft}), (0.69776 \text{ ft})]$$

$$L_{e,req} = 6.524 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.524 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.86987$$

Status: **PASS**
Ratio: **0.870**

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

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

$$q = \frac{(6.142 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.86892\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.86892\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.43446$$

Status: **PASS**
Ratio: **0.430**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.66233\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.451\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.451\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.66233\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (5.451\ \mathrm{kipft/ft})) + (4 \times (-0.66233\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2362\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.451\ \mathrm{kipft/ft})) + (3 \times (-0.66233\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (5.451\ \mathrm{kipft/ft})) + (2 \times (-0.66233\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.15542\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (5.451\ \mathrm{kipft/ft})) + ((-0.66233\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.99436\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2362\ \mathrm{ft})}{2}$$

$$p_a = 0.39272\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.15542\ \mathrm{kip/ft^2}\right)}{\left(0.39272\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.39576$$

Status: **PASS**
Ratio: **0.400**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.99436\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88387$$

Status: **PASS**
Ratio: **0.880**

Considering z-direction:

$H_o = -0.048333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.028\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.028\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.028\ \mathrm{kipft/ft})) + (4 \times (-0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.5601\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.028\ \mathrm{kipft/ft})) + (3 \times (-0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.028\ \mathrm{kipft/ft})) + (2 \times (-0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.03109\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.028\ \mathrm{kipft/ft})) + ((-0.048333\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = -0.051356\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5601\ \mathrm{ft})}{2}$$

$$p_a = 0.41701\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.03109\ \mathrm{kip/ft^2}\right)}{\left(0.41701\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.074555$$

Status: **PASS**
Ratio: **-0.070**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

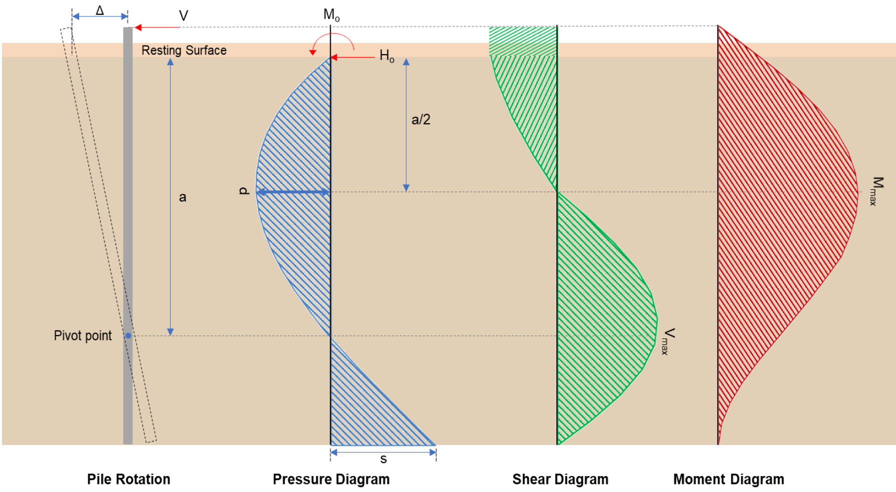
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.051356\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.04565$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.32\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.1067\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.401\ \mathrm{kipft}) + ((-3.32\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.1337\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.1337\ \mathrm{kipft/ft})}{(-1.1067\ \mathrm{kip/ft})}$$

$$E = 8.2533\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1337\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-1.1067\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (9.1337\ \mathrm{kipft/ft})) + (4 \times (-1.1067\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2358\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1067\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.2533\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2358\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.2533\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2358\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.6561 \text{ kip}$$

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

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

$$M_{max} = ((-1.1067 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(8.2533 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.2533 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.2533 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.2358 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 30.214 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.221 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.073667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.13 \text{ kipft}) + ((-0.221 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.043333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.043333 \text{ kipft/ft})}{(-0.073667 \text{ kip/ft})}$$

$$E = 0.58824 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.043333 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.073667 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.043333 \text{ kipft/ft})) + (4 \times (-0.073667 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.5592 \text{ ft}$$

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

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

$$V_{max} = ((-0.073667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.5592 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.5592 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.18136 \text{ kip}$$

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

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

$$M_{max} = ((-0.073667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(0.58824 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (0.58824 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.5592 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.53459 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.103 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -37.089 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.089 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.85\ \left[\left(0.85\, f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(9.103\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$ $$Ratio = 0.0072597$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\ \mathrm{in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\ \mathrm{in})$$ $$d = 28.8\ \mathrm{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,max} = 186.09\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 9.103\ \mathrm{kip} \rightarrow 9103\ \mathrm{lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(9103\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,a} = 75.983\ \mathrm{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$ $$V_{c,b} = 204.04\ \mathrm{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\ \mathrm{kip}), (75.983\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$	

$$V_c = 75.983\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.983\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.2\ \text{kip}$$

Considering x-direction:

$V_{max} = 8.6561\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.6561\ \text{kip})}{(74.2\ \text{kip})}$$

$$Ratio = 0.11666$$

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

Considering z-direction:

$V_{max} = 0.18136\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.18136\ \text{kip})}{(74.2\ \text{kip})}$$

$$Ratio = 0.0024442$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$S_m = 4580.4\ \text{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 30.214\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(30.214\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.48711$$	Status: **PASS** Ratio: **0.490**
	Considering z-direction: $M_{max} = 0.53459\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.53459\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.0086187$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

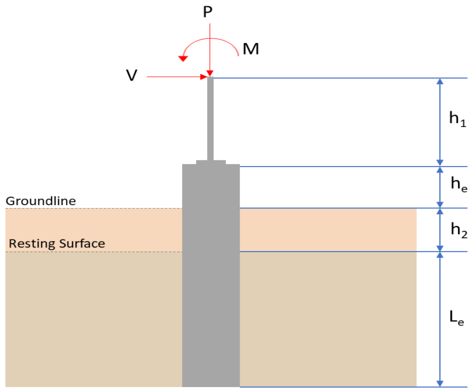
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 7.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.986	10.377
V_x (kip)	-2.283	-3.807
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	18.666	31.262

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.283\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.761\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

	$$M_o = \frac{(18.666\ \mathrm{kipft}) + ((-2.283\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$ $$M_o = 6.222\ \mathrm{kipft/ft}$$ 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: $L_{e,x} = 6.7024\ \mathrm{ft}$ - Required depth in x-direction, **Considering z-direction:** $L_{e,z} = 0\ \mathrm{ft}$ - Required depth in z-direction, **Minimum embedded depth required:** $L_{e,req}$ - Depth of pile required, $$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$ $$L_{e,req} = MAX[(6.7024\ \mathrm{ft}), (0\ \mathrm{ft})]$$ $$L_{e,req} = 6.702\ \mathrm{ft}$$ L_e - Actual embedded length of pile, $$L_e = L - h_e - h_2$$ $$L_e = (7.75\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$ $$L_e = 7.75\ \mathrm{ft}$$ $Ratio$ - Embedded depth $$Ratio = \frac{L_{e,req}}{L_e}$$ $$Ratio = \frac{(6.702\ \mathrm{ft})}{(7.75\ \mathrm{ft})}$$ $$Ratio = 0.86477$$	Status: **PASS** Ratio: **0.860**
	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 $$q = \frac{P_v}{A}$$ $$q = \frac{(6.986\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$ $$q = 0.98832\ \mathrm{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.98832\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$ $$Ratio = 0.49416$$	Status: **PASS** Ratio: **0.490**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(7.75\ \mathrm{ft})}{(36\ \mathrm{in})}$$	

$$L/D = 2.5833$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.761\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.222\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.222\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.761\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (6.222\ \text{kipft/ft})) + (4 \times (-0.761\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.4168\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.222\ \text{kipft/ft})) + (3 \times (-0.761\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (6.222\ \text{kipft/ft})) + (2 \times (-0.761\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = 0.14777\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (6.222\ \text{kipft/ft})) + ((-0.761\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 1.0272\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.4168\ \text{ft})}{2}$$

$$p_a = 0.40626\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.14777\ \text{kip/ft}^2\right)}{\left(0.40626\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.36373$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (7.75\ \text{ft})$$

$$p_s = 1.1625\ \text{kip/ft}^2$$

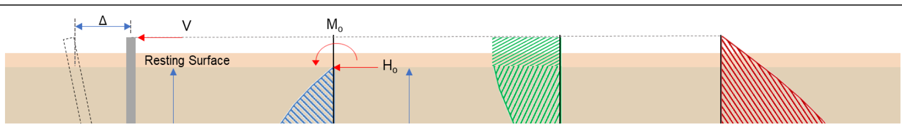
$Ratio$ - Lateral soil capacity

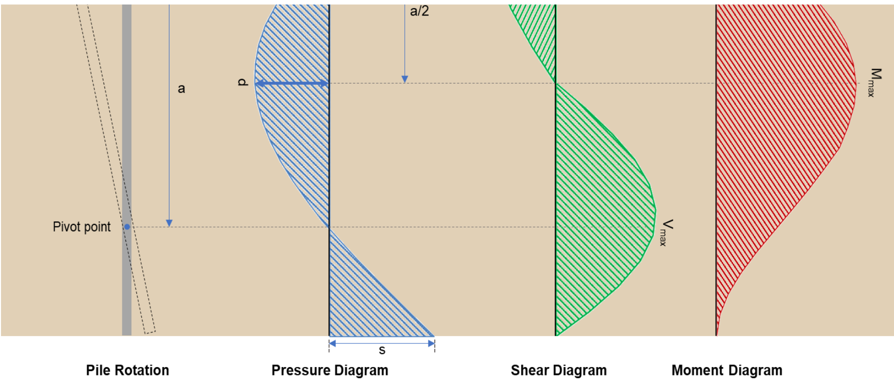
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0272\ \text{kip/ft}^2\right)}{\left(1.1625\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.88364$$

Status: **PASS**
Ratio: **0.880**





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.807 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.269 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.262 \text{ kipft}) + ((-3.807 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.421 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.421 \text{ kipft/ft})}{(-1.269 \text{ kip/ft})}$$

$$E = 8.2117 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.421 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-1.269 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (10.421 \text{ kipft/ft})) + (4 \times (-1.269 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4161 \text{ ft}$$

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

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

$$V_{max} = ((-1.269 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.2117 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.4161 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.2117 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.4161 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 9.6512 \text{ kip}$$

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

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

$$M_{max} = ((-1.269 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(8.2117 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.4161 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.2117 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.4161 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.2117 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.4161 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 34.738 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5$ ksi - Concrete strength,
$f_{yk} = 60$ 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.377 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -37.049 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.049 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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. 10⌀: 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**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.377\text{ kip})}{(1253.9\text{ kip})}$$ $$Ratio = 0.0082757$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (36\text{ in})$$ $$d = 28.8\text{ in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,max} = 186.09\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 10.377\text{ kip} \rightarrow 10377\text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + \frac{(10377\text{ lbf})}{6 \times (1017.9\text{ in}^2)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,a} = 76.2\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$ $$V_{c,b} = 204.04\text{ kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(186.09\text{ kip}), (76.2\text{ kip}), (204.04\text{ kip})\right]$$	

	$$V_c = 76.2 \text{ kip}$$		

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.2 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.34 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.6512 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.6512 \text{ kip})}{(74.34 \text{ kip})}$$

$$Ratio = 0.12982$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

	$$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 34.738\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(34.738\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.56005$$	Status: **PASS** Ratio: **0.560**