Your Project Calculations

Project Name: MTSOLAR_IC0A5GEE34F8

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_IC0A5GEE34F8&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=bWCPeFMD18gzSOIc3cnGLCf81uOhbJJMLIbrAOhMTjgEsR3LBYnHdigQOeKmoq3A

Array Specification

Product:	Beam
Unique ID:	4P-19.75-6TOP-SD-24-L-4Hx10W-9GE1
Duty Classification:	SD
Module Width:	41.26 in
Module Length:	83.94in
Number of Rows:	4
Number of Columns:	10
Total Number of Modules:	40
Desired Tilt Angle:	46
Front Edge Clearance:	9
Total Array Height at Tilt:	18.95 ft
Total Frame Length:	70.75 ft
Frame Weight:	3485 lbs
Array Dimensions N/S:	13.92 ft
Array Dimensions E/W:	70.78 ft
Rail Length:	167.04 in
Rail Spacing:	3.50 ft
Rail Check:	Not Checked

Support Specifications

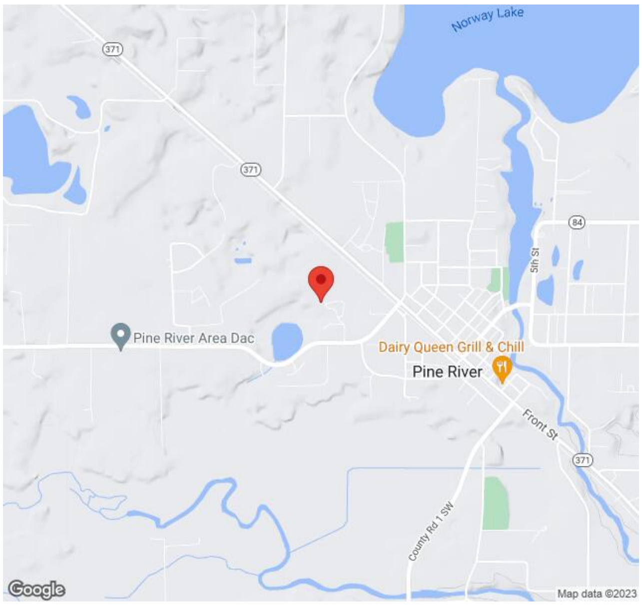
Pole Size:	6in Pipe Sch 80
Pole Length above Grade:	14.01 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.75 ft Pile 2: 6.25 ft Pile 3: 6.25 ft Pile 4: 5.75 ft
Foundation Volume:	14.222 y^3
Foundation Result:	PASSED
Mount Twist:	1.073714 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	2331 Dancing Wind Rd SW, Pine River, MN 56474, USA
Wind Speed:	101 mph
Snow Load:	60 psf
Design Uplift Pressure:	0.013136 ksf
Design Downforce Pressure:	-0.013136 ksf
Design Snow Pressure:	0.015835 ksf



Design Disclaimer

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

AutoDesigner Input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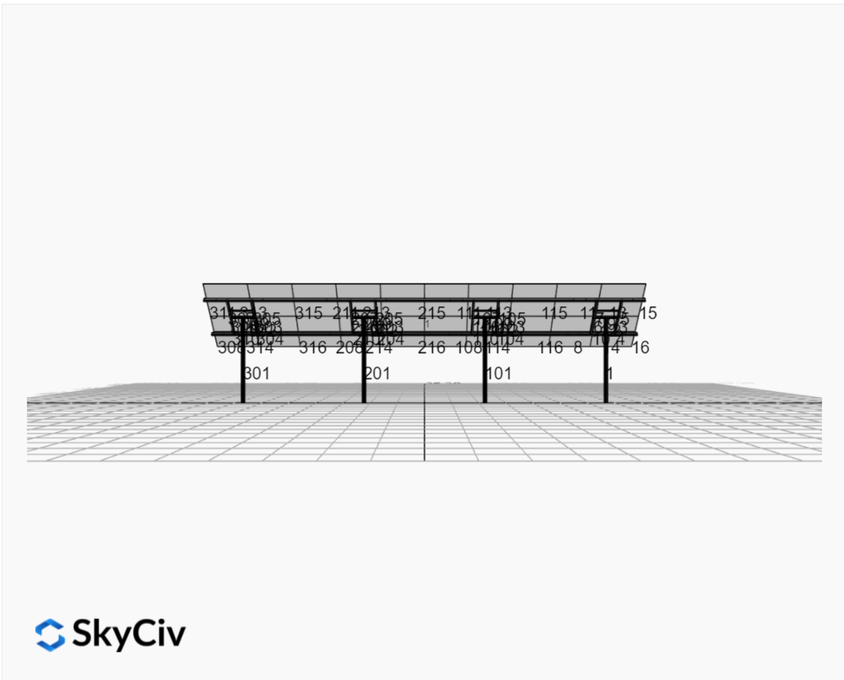
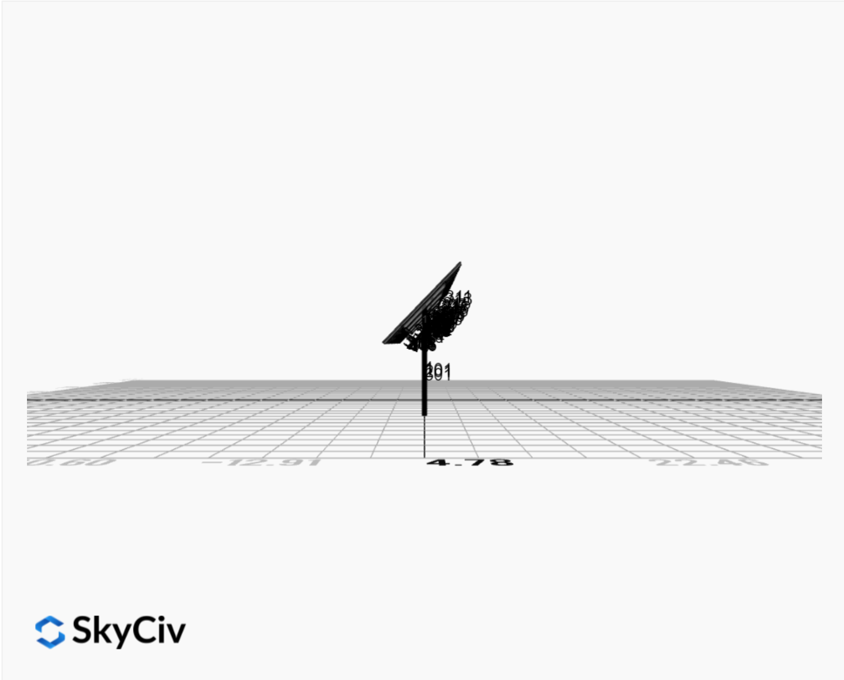
Design Notes:

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

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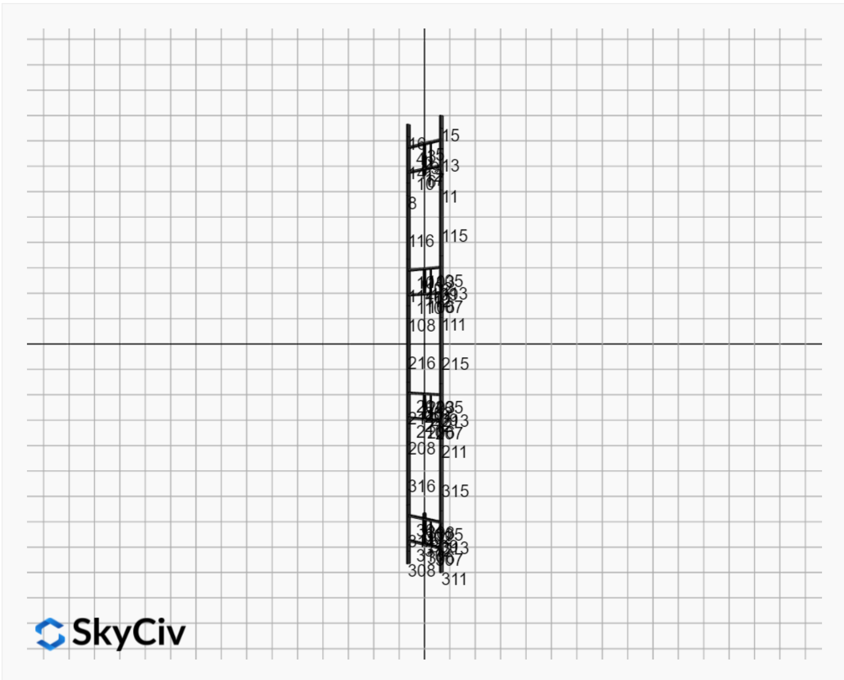
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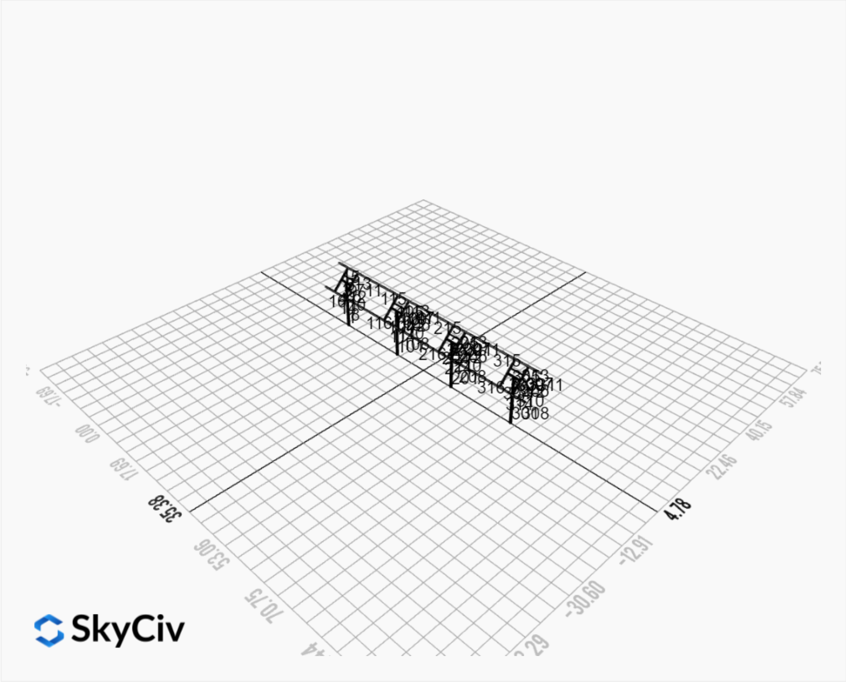
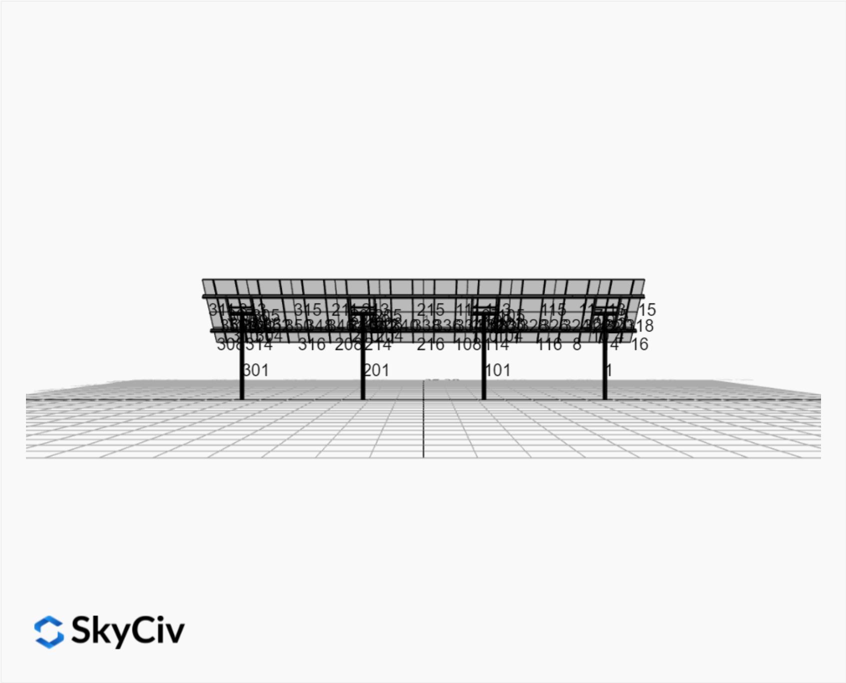
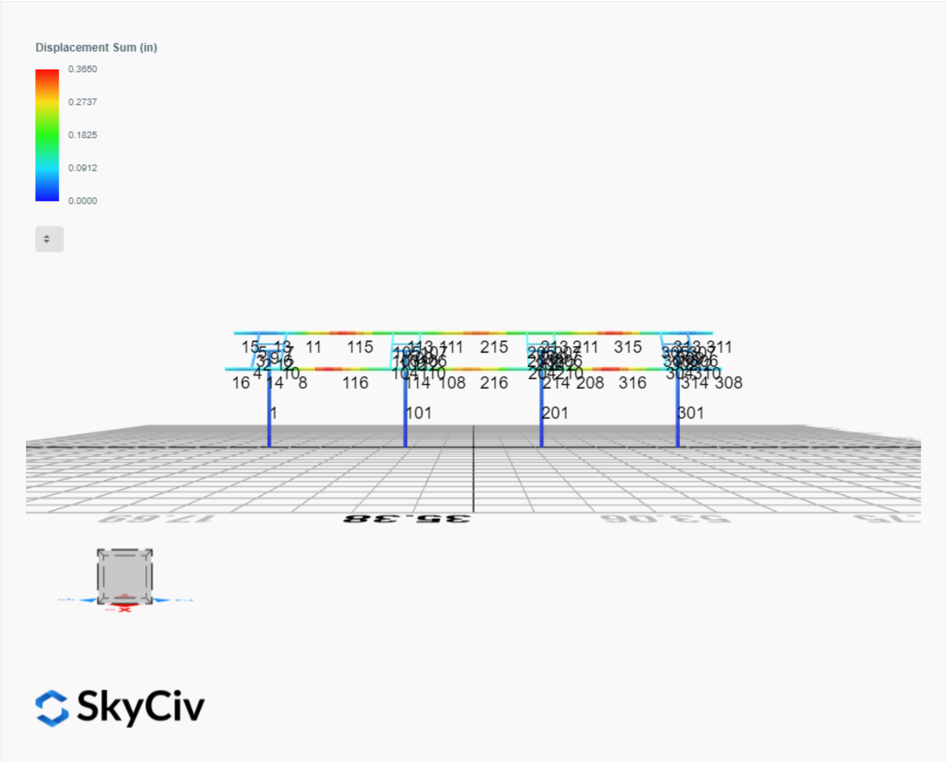
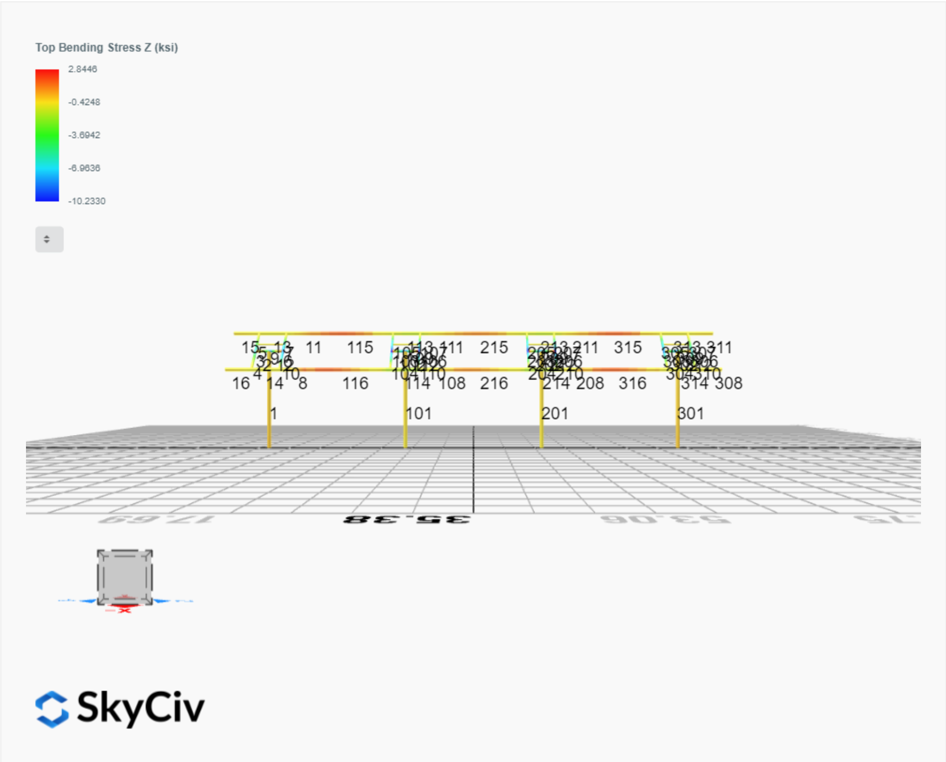
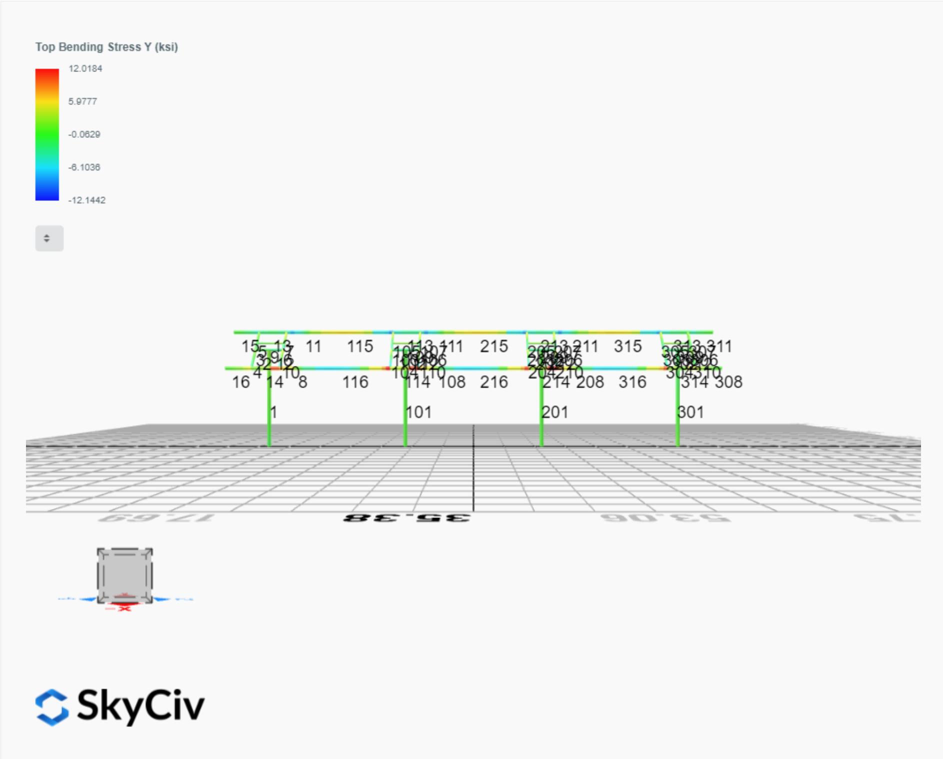

SkyCiv


301
201
101
SkyCiv

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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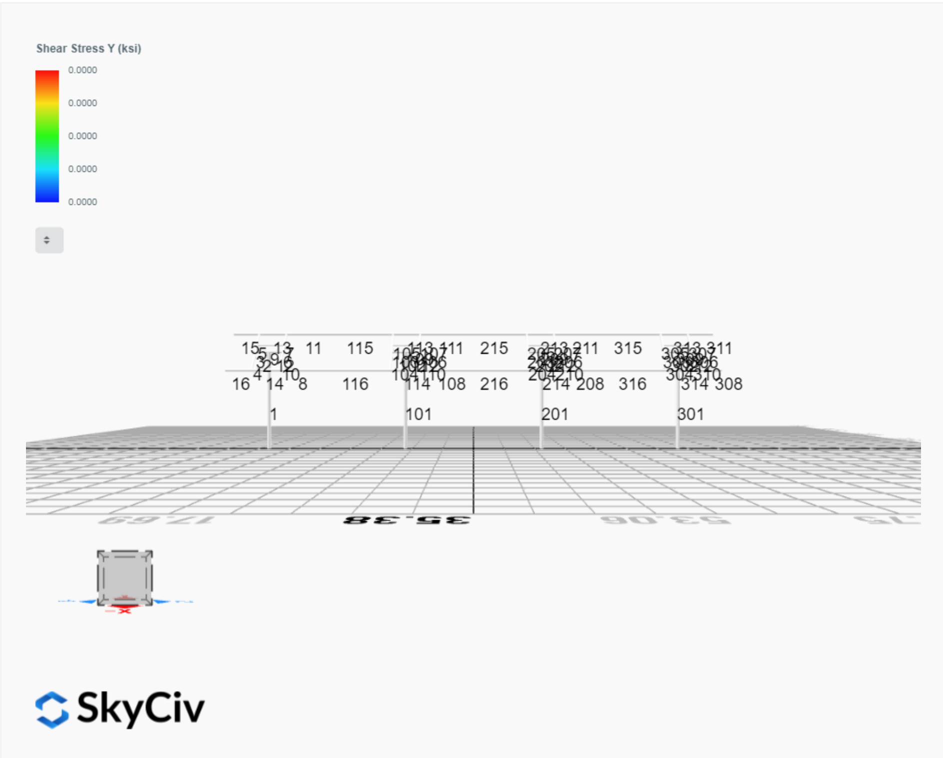
-0.0629
-6.1036
-12.1442


Shear Stress Y (ksi)
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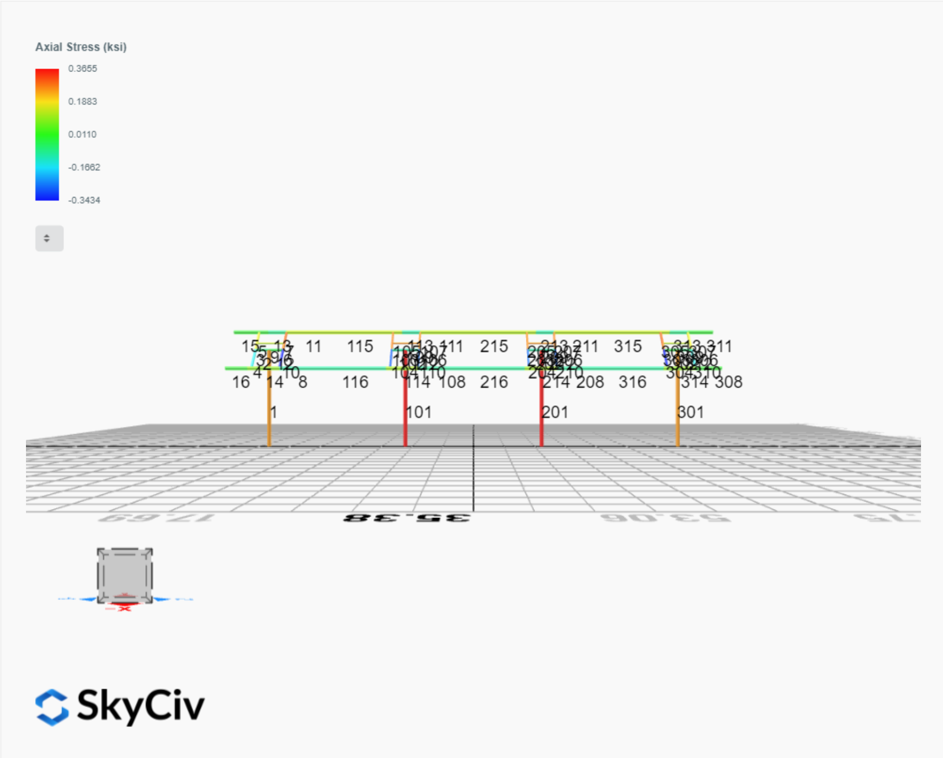
0.0000
0.0000
0.0000
0.0000


Axial Stress (ksi)
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-0.3434
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11
115
215
315
16
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
35.38
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	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 2. D + L	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 3. D + (S or Lr or R)	0.0522	4.1553	0.1663	0.7388	-0.2657	-0.6639
ULS: 3. D + (S or Lr or R)	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0437	3.5692	0.1393	0.6191	-0.2222	-0.5535
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 5b. D + 0.7E	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0437	3.5692	0.1393	0.6191	-0.2222	-0.5535
ULS: 8. 0.6D + 0.7E	0.0109	1.0865	0.0349	0.1561	-0.0551	-0.1334
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.2349	2.9563	0.1753	0.7520	-0.5988	17.7531
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2664	0.6619	-0.0615	-0.2807	0.4066	-17.5827
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8962	4.4282	0.2271	0.9881	-0.6025	12.9281
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0437	3.5692	0.1393	0.6191	-0.2222	-0.5535
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9798	2.7074	0.0495	0.2135	0.1515	-13.5738
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0437	3.5692	0.1393	0.6191	-0.2222	-0.5535
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9216	2.6699	0.1460	0.6291	-0.4721	13.2592
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9544	0.9491	-0.0316	-0.1455	0.2820	-13.2426
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0182	1.8109	0.0582	0.2601	-0.0918	-0.2223
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.2422	2.2319	0.1520	0.6480	-0.5621	17.8420
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0109	1.0865	0.0349	0.1561	-0.0551	-0.1334
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2591	-0.0625	-0.0848	-0.3847	0.4433	-17.4937
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0109	1.0865	0.0349	0.1561	-0.0551	-0.1334

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	6.8745
Shear X	-2.1229
Shear Z	0.3492
Moment X	1.4915
Moment Y (Twist)	1.0849
Moment Z	30.3306

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	4.4282
Shear X	-1.2664
Shear Z	0.2271
Moment X	0.9881
Moment Y (Twist)	0.6025
Moment Z	17.8420

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	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 2. D + L	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 3. D + (S or Lr or R)	-0.0522	5.2745	-0.0084	-0.0409	0.0175	0.7149
ULS: 3. D + (S or Lr or R)	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0437	4.5065	-0.0070	-0.0340	0.0147	0.5999
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 5b. D + 0.7E	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0437	4.5065	-0.0070	-0.0340	0.0147	0.5999
ULS: 8. 0.6D + 0.7E	-0.0109	1.3214	-0.0017	-0.0080	0.0037	0.1529
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5581	3.7541	0.0123	0.0463	-0.0979	22.1171
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5266	0.6542	-0.0196	-0.0889	0.1106	-20.7977
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1986	5.6703	0.0043	0.0107	-0.0634	16.9966
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0437	4.5065	-0.0070	-0.0340	0.0147	0.5999
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1149	3.3453	-0.0196	-0.0907	0.0929	-15.1895
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0437	4.5065	-0.0070	-0.0340	0.0147	0.5999
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1731	3.3662	0.0085	0.0313	-0.0718	16.6516
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1404	1.0412	-0.0154	-0.0700	0.0845	-15.5346
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0182	2.2024	-0.0029	-0.0134	0.0062	0.2548
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5508	2.8732	0.0134	0.0516	-0.1003	22.0152
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0109	1.3214	-0.0017	-0.0080	0.0037	0.1529
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5339	-0.2268	-0.0185	-0.0835	0.1081	-20.8996
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0109	1.3214	-0.0017	-0.0080	0.0037	0.1529

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.8564
Shear X	-2.6009
Shear Z	-0.0353
Moment X	-0.1605
Moment Y (Twist)	0.1947
Moment Z	38.1528

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.6703
Shear X	-1.5581
Shear Z	-0.0196
Moment X	-0.0907
Moment Y (Twist)	0.1106
Moment Z	22.1171

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	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 2. D + L	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 3. D + (S or Lr or R)	-0.0522	5.2745	0.0084	0.0397	-0.0181	0.7152
ULS: 3. D + (S or Lr or R)	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0437	4.5065	0.0070	0.0331	-0.0151	0.6002
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 5b. D + 0.7E	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0437	4.5065	0.0070	0.0331	-0.0151	0.6002
ULS: 8. 0.6D + 0.7E	-0.0109	1.3214	0.0017	0.0080	-0.0038	0.1530
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5581	3.7542	-0.0123	-0.0466	0.0976	22.1182
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5267	0.6541	0.0196	0.0892	-0.1106	-20.7976
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1986	5.6704	-0.0044	-0.0118	0.0627	16.9976
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0437	4.5065	0.0070	0.0331	-0.0151	0.6002
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1150	3.3453	0.0196	0.0900	-0.0934	-15.1893
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0437	4.5065	0.0070	0.0331	-0.0151	0.6002

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	-1.1732	3.3663	-0.0085	-0.0316	0.0716	16.6523
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1404	1.0412	0.0154	0.0702	-0.0845	-15.5345
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0182	2.2024	0.0028	0.0133	-0.0063	0.2549
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5508	2.8733	-0.0134	-0.0519	0.1001	22.0162
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0109	1.3214	0.0017	0.0080	-0.0038	0.1530
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5340	-0.2268	0.0185	0.0838	-0.1081	-20.8996
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0109	1.3214	0.0017	0.0080	-0.0038	0.1530

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.8548
Shear X	-2.6002
Shear Z	0.0351
Moment X	0.1601
Moment Y (Twist)	0.1938
Moment Z	38.1482

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.6704
Shear X	-1.5581
Shear Z	0.0196
Moment X	0.0900
Moment Y (Twist)	0.1106
Moment Z	22.1182

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	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 2. D + L	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 3. D + (S or Lr or R)	0.0522	4.1552	-0.1662	-0.7394	0.2642	-0.6623
ULS: 3. D + (S or Lr or R)	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0437	3.5691	-0.1392	-0.6196	0.2211	-0.5522
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 5b. D + 0.7E	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0437	3.5691	-0.1392	-0.6196	0.2211	-0.5522
ULS: 8. 0.6D + 0.7E	0.0109	1.0865	-0.0349	-0.1561	0.0550	-0.1332
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.2349	2.9562	-0.1753	-0.7524	0.5986	17.7540
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2664	0.6619	0.0615	0.2805	-0.4067	-17.5813
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8961	4.4281	-0.2270	-0.9888	0.6012	12.9298
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0437	3.5691	-0.1392	-0.6196	0.2211	-0.5522
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9799	2.7074	-0.0494	-0.2141	-0.1527	-13.5717
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0437	3.5691	-0.1392	-0.6196	0.2211	-0.5522
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9216	2.6699	-0.1460	-0.6293	0.4718	13.2600
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9544	0.9492	0.0316	0.1453	-0.2821	-13.2415
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0182	1.8109	-0.0582	-0.2602	0.0917	-0.2220
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.2422	2.2319	-0.1520	-0.6483	0.5619	17.8428
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0109	1.0865	-0.0349	-0.1561	0.0550	-0.1332
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2591	-0.0624	0.0848	0.3846	-0.4433	-17.4925
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0109	1.0865	-0.0349	-0.1561	0.0550	-0.1332

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	6.8742
Shear X	-2.1228
Shear Z	-0.3467
Moment X	-1.4944
Moment Y (Twist)	1.0737
Moment Z	30.3369

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	4.4281
Shear X	-1.2664
Shear Z	-0.2270
Moment X	-0.9888
Moment Y (Twist)	0.6012
Moment Z	17.8428

Project Details

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

User Name: sales@mtsolar.us
Project Name: MTSOLAR_IC0A5GEE34F8
Unit System: imperial

Design Input Information

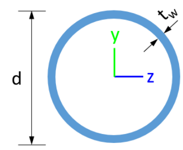
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

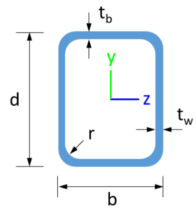
Design Materials

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

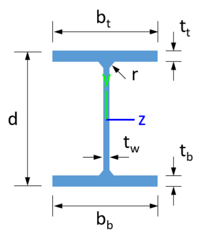
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
8	6in Pipe Sch 80	6.63	0.43					



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



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

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31

8	6in Pipe Sch 80	8.40	80.98	40.49	40.49	0.00	16.60	16.60
15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	8	29.41	29.41	14.01	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.18,1.13,1.18,1.17,1.18,1.15,1.18,1.17,1.17,1.18,1.17,1.17,1.18,1.09,1.18,1.17,1.18,1.16,1.18	300	200	1
4	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.58,1.69,1.67,1.69,1.66,1.69	300	200	1
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.61,1.68,1.67,1.68,1.66,1.68	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.17,1.19,1.19,1.19,1.18,1.19	300	200	1
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
8	18	1.33	1.33	2.05	1.53,1.67,1.49,2.11,1.56,1.45,1.22,1.67,2.18,1.67,1.27,1.49,1.78,1.49,1.73,2.11,2.18,2.11,1.23,1.49,2.16,1.49,1.33,1.45,1.54,1.45	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
11	18	1.33	1.33	2.05	1.33,1.37,1.33,1.65,1.34,1.33,1.04,1.37,2.23,1.37,1.38,1.33,2.14,1.33,1.21,1.65,2.15,1.65,1.17,1.33,2.24,1.33,1.54,1.33,2.06,1.33	300	200	1
12	4	2.00	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.14,1.14,1.14,1.13,1.14,1.14,1.09,1.14,2.27,1.14,1.09,1.14,1.33,1.14,1.10,1.13,2.05,1.13,1.10,1.14,1.87,1.14,1.09,1.14,1.17,1.14	300	200	1
14	18	4.88	4.00	7.50	1.15,1.20,1.15,1.51,1.15,1.15,1.15,1.20,2.84,1.20,1.15,1.15,1.22,1.15,1.14,1.51,2.40,1.51,1.14,1.15,2.41,1.15,1.15,1.15,1.19,1.15	300	200	1
15	18	4.20	4.20	2.00	2.11,2.00,2.14,1.66,2.09,2.19,2.42,2.00,2.32,2.00,2.49,2.14,2.50,2.14,2.41,1.66,2.33,1.66,2.31,2.14,2.33,2.14,2.20,2.19,1.61,2.19	300	200	1
16	18	4.20	4.20	2.00	2.45,2.44,2.46,2.40,2.45,2.47,2.23,2.44,2.32,2.44,1.65,2.46,2.42,2.46,1.73,2.40,2.31,2.40,1.55,2.46,2.32,2.46,1.73,2.47,2.29,2.47	300	200	1
101	8	29.41	29.41	14.01	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.13,1.18,1.18,1.18,1.17,1.18	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
105	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	30	20	1

						0	0	
108	18	1.33	1.33	2.05	2.16,2.18,2.15,2.21,2.16,2.14,1.26,2.18,2.21,2.18,1.06,2.15,2.09,2.15,2.11,2.21,2.28,2.21,1.60,2.15,2.18,2.15,1.31,2.14,1.57,2.14	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
111	18	1.33	1.33	2.05	2.03,2.01,2.03,2.04,2.02,2.05,1.86,2.01,2.16,2.01,1.32,2.03,1.79,2.03,1.85,2.04,2.28,2.04,1.18,2.03,2.05,2.03,1.06,2.05,1.46,2.05	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.06,4.38,1.06,1.09,1.06,1.20,1.06,1.07,1.06,1.44,1.06,1.08,1.06,3.38,1.06,1.09,1.06,1.17,1.06	300	200	1
114	18	4.88	4.00	7.50	1.05,1.08,1.05,1.19,1.05,1.05,1.06,1.08,1.91,1.08,1.07,1.05,1.11,1.05,1.06,1.19,1.73,1.19,1.06,1.05,1.71,1.05,1.07,1.05,1.10,1.05	300	200	1
115	18	6.63	6.63	10.20	1.14,1.14,1.14,1.15,1.14,1.14,1.09,1.14,1.08,1.14,1.09,1.14,1.09,1.14,1.12,1.15,1.21,1.15,1.10,1.14,1.09,1.14,1.09,1.14,1.10,1.14	300	200	1
116	18	6.63	6.63	10.20	1.16,1.16,1.16,1.17,1.16,1.16,1.14,1.16,1.15,1.16,1.13,1.16,1.16,1.16,1.16,1.17,1.19,1.17,1.14,1.16,1.12,1.16,1.13,1.16,1.16,1.16	300	200	1
201	8	29.41	29.41	14.01	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
205	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.64,1.68,1.67,1.67,1.66,1.67	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.13,1.18,1.18,1.18,1.17,1.18	300	200	1
207	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.67,1.68	300	200	1
208	18	1.33	1.33	2.05	2.12,2.14,2.11,2.19,2.12,2.10,1.50,2.14,2.16,2.14,1.44,2.11,1.06,2.11,2.10,2.19,2.24,2.19,1.14,2.11,2.14,2.11,1.35,2.10,1.60,2.10	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
211	18	1.33	1.33	2.05	1.67,1.65,1.69,1.83,1.67,1.73,1.93,1.65,1.96,1.65,1.69,1.69,1.06,1.69,1.57,1.83,2.24,1.83,1.35,1.69,1.69,1.69,1.58,1.73,1.20,1.73	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.06,4.39,1.06,1.09,1.06,1.20,1.06,1.07,1.06,1.45,1.06,1.08,1.06,3.38,1.06,1.09,1.06,1.17,1.06	300	200	1
214	18	4.88	4.00	7.50	1.05,1.08,1.05,1.21,1.05,1.05,1.06,1.08,1.92,1.08,1.07,1.05,1.11,1.05,1.06,1.21,1.73,1.21,1.06,1.05,1.72,1.05,1.07,1.05,1.10,1.05	300	200	1
215	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.12,1.16,1.07,1.16,1.12,1.16,1.09,1.16,1.14,1.16,1.21,1.16,1.13,1.16,1.06,1.16,1.12,1.16,1.10,1.16	300	200	1
216	18	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.11,1.17,1.15,1.17,1.13,1.17,1.16,1.17,1.20,1.17,1.15,1.17,1.10,1.17,1.15,1.17,1.14,1.17	300	200	1
301	8	29.41	29.41	14.01	-	300	200	1

302	4	2.00	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.19,1.17,1.19,1.19,1.19,1.18,1.19	300	200	1
304	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
305	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
306	15	0.92	0.92	1.42	1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.18,1.13,1.18,1.17,1.18,1.15,1.18,1.17,1.17,1.18,1.17,1.17,1.18,1.09,1.18,1.17,1.18,1.16,1.18	300	200	1
307	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.61,1.68,1.67,1.68,1.66,1.68	300	200	1
308	18	4.20	4.20	2.00	2.45,2.44,2.46,2.40,2.45,2.47,2.22,2.44,2.32,2.44,1.64,2.46,2.42,2.46,1.73,2.40,2.31,2.40,1.55,2.46,2.32,2.46,1.73,2.47,2.29,2.47	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.58,1.69,1.67,1.69,1.66,1.69	300	200	1
311	18	4.20	4.20	2.00	2.11,2.00,2.14,1.66,2.09,2.19,2.42,2.00,2.32,2.00,2.49,2.14,2.50,2.14,2.41,1.66,2.33,1.66,2.31,2.14,2.33,2.14,2.20,2.19,1.61,2.19	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.14,1.14,1.14,1.14,1.14,1.14,1.09,1.14,2.28,1.14,1.09,1.14,1.34,1.14,1.11,1.14,1.99,1.14,1.10,1.14,1.87,1.14,1.09,1.14,1.17,1.14	300	200	1
314	18	4.88	4.00	7.50	1.15,1.17,1.15,1.43,1.15,1.15,1.15,1.17,2.85,1.17,1.15,1.15,1.22,1.15,1.14,1.43,2.36,1.43,1.14,1.15,2.41,1.15,1.15,1.15,1.19,1.15	300	200	1
315	18	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.12,1.09,1.10,1.09,1.13,1.09,1.10,1.09,1.10,1.09,1.09,1.09,1.11,1.09,1.16,1.09,1.13,1.09,1.10,1.09	300	200	1
316	18	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.08,1.09,1.09,1.09,1.09,1.09	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	378.22	73.42	62.23	62.23	113.47	113.47
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	140.22	16.17	16.17	42.85	42.85
13	120.60	98.23	19.19	6.45	30.09	45.74
14	120.60	98.23	20.07	6.45	30.09	45.74
15	120.60	96.18	23.36	6.45	30.09	45.74
16	120.60	96.18	23.36	6.45	30.09	45.74
101	378.22	73.42	62.23	62.23	113.47	113.47
102	142.83	141.72	16.17	16.17	42.85	42.85

103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	18.66	6.45	30.09	45.74
114	120.60	98.23	18.49	6.45	30.09	45.74
115	120.60	68.63	14.75	6.45	30.09	45.74
116	120.60	68.63	15.30	6.45	30.09	45.74
201	378.22	73.42	62.23	62.23	113.47	113.47
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61
208	120.60	117.88	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	117.88	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	18.66	6.45	30.09	45.74
214	120.60	98.23	18.49	6.45	30.09	45.74
215	120.60	68.63	14.48	6.45	30.09	45.74
216	120.60	68.63	15.03	6.45	30.09	45.74
301	378.22	73.42	62.23	62.23	113.47	113.47
302	142.83	140.22	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	4.60	29.14	16.61
304	79.65	72.01	10.99	4.60	29.14	16.61
305	79.65	73.44	10.99	4.60	29.14	16.61
306	79.65	74.02	10.99	4.60	29.14	16.61
307	79.65	73.44	10.99	4.60	29.14	16.61
308	120.60	96.18	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	4.60	29.14	16.61
311	120.60	96.18	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	98.23	19.19	6.45	30.09	45.74
314	120.60	98.23	20.07	6.45	30.09	45.74
315	120.60	68.63	14.89	6.45	30.09	45.74
316	120.60	68.63	14.75	6.45	30.09	45.74

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.094	0.487	0.055	0.019	0.003	0.546	#13	0.804	Not Required	Pass
2	0.002	0.195	0.109	0.052	0.023	0.270	#21	0.034	Not Required	Pass
3	0.010	0.342	0.058	0.033	0.012	0.394	#21	0.044	Not Required	Pass

4	0.008	0.344	0.162	0.035	0.023	0.500	#21	0.078	Not Required	Pass
5	0.009	0.212	0.124	0.034	0.018	0.232	#13	0.073	Not Required	Pass
6	0.017	0.540	0.280	0.056	0.057	0.828	#21	0.044	Not Required	Pass
7	0.018	0.334	0.391	0.054	0.057	0.454	#21	0.073	Not Required	Pass
8	0.004	0.152	0.139	0.095	0.015	0.235	#23	0.088	Not Required	Pass
9	0.007	0.049	0.091	0.005	0.005	0.114	#21	0.198	Not Required	Pass
10	0.017	0.516	0.370	0.052	0.047	0.725	#21	0.078	Not Required	Pass
11	0.005	0.117	0.145	0.069	0.017	0.205	#23	0.088	Not Required	Pass
12	0.001	0.422	0.225	0.435	0.410	0.528	#21	0.079	Not Required	Pass
13	0.007	0.081	0.385	0.053	0.025	0.452	#23	0.265	Not Required	Pass
14	0.004	0.110	0.377	0.075	0.020	0.475	#23	0.265	Not Required	Pass
15	0.000	0.024	0.040	0.019	0.006	0.061	#23	0.278	Not Required	Pass
16	0.000	0.029	0.041	0.023	0.006	0.070	#23	0.278	Not Required	Pass
101	0.120	0.613	0.005	0.024	0.000	0.660	#13	0.804	Not Required	Pass
102	0.004	0.407	0.156	0.100	0.029	0.535	#21	0.034	Not Required	Pass
103	0.017	0.570	0.197	0.057	0.029	0.776	#21	0.044	Not Required	Pass
104	0.016	0.587	0.414	0.059	0.052	0.882	#21	0.078	Not Required	Pass
105	0.017	0.353	0.429	0.057	0.064	0.469	#21	0.073	Not Required	Pass
106	0.017	0.582	0.180	0.059	0.026	0.770	#21	0.044	Not Required	Pass
107	0.017	0.361	0.396	0.059	0.060	0.479	#21	0.073	Not Required	Pass
108	0.005	0.116	0.139	0.088	0.016	0.253	#23	0.088	Not Required	Pass
109	0.017	0.045	0.058	0.002	0.000	0.100	#21	0.198	Not Required	Pass
110	0.016	0.580	0.374	0.058	0.047	0.847	#21	0.078	Not Required	Pass
111	0.006	0.081	0.149	0.059	0.018	0.224	#23	0.088	Not Required	Pass
112	0.004	0.409	0.162	0.099	0.034	0.540	#21	0.034	Not Required	Pass
113	0.007	0.145	0.417	0.053	0.023	0.486	#23	0.265	Not Required	Pass
114	0.007	0.170	0.420	0.077	0.022	0.537	#21	0.265	Not Required	Pass
115	0.009	0.201	0.218	0.034	0.017	0.425	#21	0.439	Not Required	Pass
116	0.004	0.205	0.222	0.038	0.017	0.428	#21	0.439	Not Required	Pass
201	0.120	0.613	0.005	0.024	0.000	0.660	#13	0.804	Not Required	Pass
202	0.004	0.409	0.162	0.099	0.034	0.540	#21	0.034	Not Required	Pass
203	0.017	0.582	0.180	0.059	0.026	0.770	#21	0.044	Not Required	Pass
204	0.016	0.580	0.374	0.059	0.047	0.846	#21	0.078	Not Required	Pass
205	0.017	0.361	0.396	0.059	0.060	0.479	#21	0.073	Not Required	Pass
206	0.017	0.570	0.197	0.058	0.029	0.776	#21	0.044	Not Required	Pass
207	0.017	0.353	0.428	0.058	0.064	0.468	#21	0.073	Not Required	Pass
208	0.004	0.122	0.172	0.092	0.017	0.241	#23	0.088	Not Required	Pass
209	0.017	0.045	0.057	0.002	0.000	0.100	#21	0.198	Not Required	Pass
210	0.016	0.587	0.413	0.059	0.052	0.882	#21	0.078	Not Required	Pass
211	0.005	0.121	0.176	0.065	0.018	0.256	#21	0.088	Not Required	Pass
212	0.004	0.407	0.156	0.100	0.029	0.534	#21	0.034	Not Required	Pass
213	0.007	0.144	0.417	0.054	0.023	0.481	#23	0.265	Not Required	Pass
214	0.007	0.169	0.418	0.079	0.022	0.544	#21	0.265	Not Required	Pass
215	0.010	0.154	0.219	0.033	0.017	0.372	#21	0.439	Not Required	Pass
216	0.006	0.142	0.220	0.034	0.017	0.363	#21	0.439	Not Required	Pass
301	0.094	0.487	0.054	0.019	0.003	0.546	#13	0.804	Not Required	Pass
302	0.001	0.420	0.224	0.433	0.408	0.526	#21	0.079	Not Required	Pass
303	0.017	0.538	0.279	0.056	0.056	0.826	#21	0.044	Not Required	Pass
304	0.017	0.515	0.370	0.052	0.047	0.723	#21	0.078	Not Required	Pass
305	0.018	0.334	0.391	0.054	0.057	0.453	#21	0.073	Not Required	Pass
306	0.010	0.344	0.058	0.033	0.012	0.396	#21	0.044	Not Required	Pass
307	0.009	0.213	0.123	0.035	0.018	0.232	#13	0.073	Not Required	Pass
308	0.000	0.029	0.041	0.023	0.006	0.070	#23	0.278	Not Required	Pass
309	0.007	0.049	0.091	0.005	0.005	0.113	#21	0.198	Not Required	Pass

309	0.007	0.049	0.091	0.005	0.005	0.115	#21	0.198	Not Required	Pass
310	0.008	0.345	0.162	0.035	0.023	0.501	#21	0.078	Not Required	Pass
311	0.000	0.024	0.040	0.019	0.006	0.061	#23	0.278	Not Required	Pass
312	0.002	0.197	0.109	0.052	0.023	0.272	#21	0.034	Not Required	Pass
313	0.007	0.081	0.385	0.049	0.025	0.448	#23	0.265	Not Required	Pass
314	0.004	0.107	0.378	0.072	0.021	0.473	#23	0.265	Not Required	Pass
315	0.009	0.208	0.219	0.032	0.017	0.423	#21	0.439	Not Required	Pass
316	0.004	0.214	0.221	0.030	0.017	0.431	#21	0.439	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/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

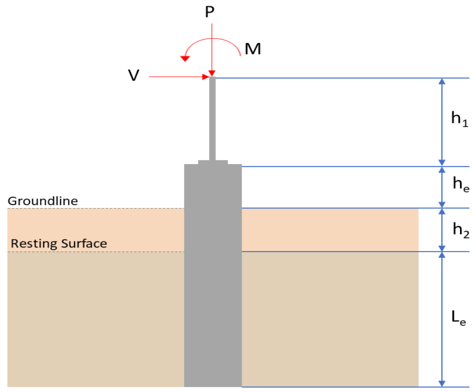
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5.75\ \text{ft}$ - 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)	4.428	6.874
V_x (kip)	-1.266	-2.123
V_z (kip)	0.227	0.349
M_x (kipft)	0.988	1.491
M_z (kipft)	17.842	30.331

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.266\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.20159\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(17.842 \text{ kipft}) + ((-1.266 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.8411 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.4449 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.227 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.036146 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.988 \text{ kipft}) + ((0.227 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.15732 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.6353 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.4449 \text{ ft}), (2.6353 \text{ ft})]$$

$$L_{e,req} = 5.445 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.445 \text{ ft})}{(5.75 \text{ ft})}$$

$$Ratio = 0.94696$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.428 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.27675 \text{ kip/ft}^2$$

$q = 0.27675 \text{ kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.27675 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.13837$$

Status: **PASS**
Ratio: **0.140**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.4375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.20159 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.8411 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.8411 \text{ kipft/ft}) \times (5.75 \text{ ft})) + \left(3 \times (-0.20159 \text{ kip/ft}) \times (5.75 \text{ ft})^2\right)}{(6 \times (2.8411 \text{ kipft/ft})) + (4 \times (-0.20159 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9358 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.8411 \text{ kipft/ft})) + (3 \times (-0.20159 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 \times [(3 \times (2.8411 \text{ kipft/ft})) + (2 \times (-0.20159 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = 0.2274 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.8411 \text{ kipft/ft})) + ((-0.20159 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.82081 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9358 \text{ ft})}{2}$$

$$p_a = 0.29518 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2274 \text{ kip/ft}^2\right)}{\left(0.29518 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.77038$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (5.75\text{ ft})$$

$$p_s = 0.8625\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.82081\text{ kip/ft}^2)}{(0.8625\text{ kip/ft}^2)}$$

$$Ratio = 0.95166$$

Status: PASS
Ratio: 0.950

Considering z-direction:

$H_o = 0.036146\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15732\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15732\text{ kipft/ft}) \times (5.75\text{ ft})) + \left(3 \times (0.036146\text{ kip/ft}) \times (5.75\text{ ft})^2\right)}{(6 \times (0.15732\text{ kipft/ft})) + (4 \times (0.036146\text{ kip/ft}) \times (5.75\text{ ft}))}$$

$$a = 4.0577\text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.15732\text{ kipft/ft})) + (3 \times (0.036146\text{ kip/ft}) \times (5.75\text{ ft}))]^2}{(5.75\text{ ft})^2 \times [(3 \times (0.15732\text{ kipft/ft})) + (2 \times (0.036146\text{ kip/ft}) \times (5.75\text{ ft}))]}$$

$$p = 0.040111\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.15732\text{ kipft/ft})) + ((0.036146\text{ kip/ft}) \times (5.75\text{ ft}))]}{(5.75\text{ ft})^2}$$

$$s = 0.094819\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\text{ psf/ft}) \times \frac{(4.0577\text{ ft})}{2}$$

$$p_a = 0.30433\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.040111\text{ kip/ft}^2)}{(0.30433\text{ kip/ft}^2)}$$

$$Ratio = 0.1318$$

Status: PASS
Ratio: 0.130

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (5.75\text{ ft})$$

$$p_s = 0.8625\text{ kip/ft}^2$$

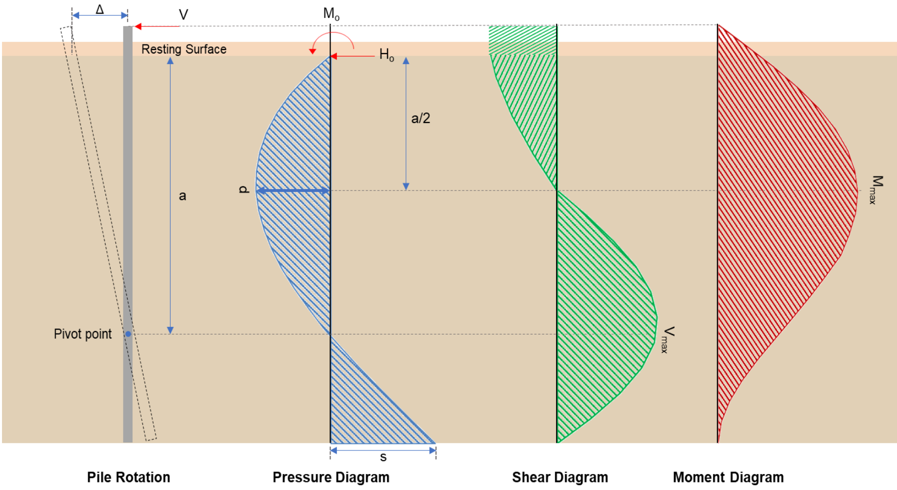
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.094819\ \text{kip/ft}^2)}{(0.8625\ \text{kip/ft}^2)}$$

$$Ratio = 0.10994$$

Status: **PASS**
Ratio: **0.110**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.123\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.33806\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.331\ \text{kipft}) + ((-2.123\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.8298\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.8298\ \text{kipft/ft})}{(-0.33806\ \text{kip/ft})}$$

$$E = 14.287\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.8298\ \text{kipft/ft}) \times (5.75\ \text{ft})) + \left(3 \times (-0.33806\ \text{kip/ft}) \times (5.75\ \text{ft})^2\right)}{(6 \times (4.8298\ \text{kipft/ft})) + (4 \times (-0.33806\ \text{kip/ft}) \times (5.75\ \text{ft}))}$$

$$a = 3.9347\ \text{ft}$$

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

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

$$V_{max} = ((-0.33806\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.287\ \text{ft})}{(5.75\ \text{ft})} + 3\right) \times \left(\frac{(3.9347\ \text{ft})}{(5.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.287\ \text{ft})}{(5.75\ \text{ft})} + 2\right) \times \left(\frac{(3.9347\ \text{ft})}{(5.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.8405\ \text{kip}$$

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

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

$$M_{max} = ((-0.33806 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[\left(\frac{(14.287 \text{ ft})}{(5.75 \text{ ft})} + \frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.287 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.287 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 18.957 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.349 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.055573 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.491 \text{ kipft}) + ((0.349 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23742 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.23742 \text{ kipft/ft})}{(0.055573 \text{ kip/ft})}$$

$$E = 4.2722 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23742 \text{ kipft/ft}) \times (5.75 \text{ ft})) + \left(3 \times (0.055573 \text{ kip/ft}) \times (5.75 \text{ ft})^2\right)}{(6 \times (0.23742 \text{ kipft/ft})) + (4 \times (0.055573 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.0599 \text{ ft}$$

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

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

$$V_{max} = ((0.055573 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2722 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.0599 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.2722 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.0599 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.43954 \text{ kip}$$

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

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

$$M_{max} = ((0.055573 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[\left(\frac{(4.2722 \text{ ft})}{(5.75 \text{ ft})} + \frac{(4.0599 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.2722 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.0599 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.2722 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.0599 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.149 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.874 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.368 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.368 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.874\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0025695$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 6.874\ \text{kip} \rightarrow 6874\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(6874\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.4\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.4\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.4\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.4\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.69\ \text{kip}$$

Considering x-direction:

$V_{max} = 6.8405\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.8405\ \text{kip})}{(110.69\ \text{kip})}$$

$$Ratio = 0.061797$$

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

Considering z-direction:

$V_{max} = 0.43954\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.43954\ \text{kip})}{(110.69\ \text{kip})}$$

$$Ratio = 0.0039708$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 18.957 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(18.957 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.075951$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $M_{max} = 1.149 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.149 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0046035$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

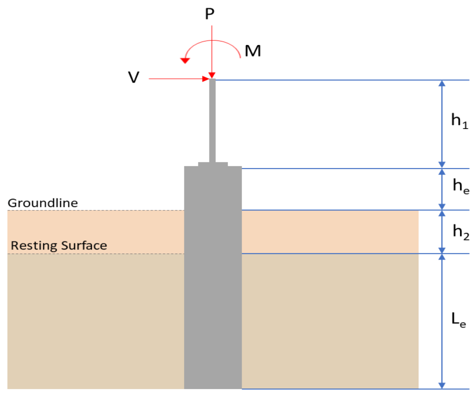
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5.75\ \text{ft}$ - 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)	4.428	6.874
V_x (kip)	-1.266	-2.123
V_z (kip)	-0.227	-0.347
M_x (kipft)	-0.989	-1.494
M_z (kipft)	17.843	30.337

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.266\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.20159\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(17.843\ \text{kipft}) + ((-1.266\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.8412\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.4451\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.227\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.036146\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.989\ \text{kipft}) + ((-0.227\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.15748\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.0182\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.4451\ \text{ft}), (2.0182\ \text{ft})]$$

$$L_{e,req} = 5.445\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.445\ \text{ft})}{(5.75\ \text{ft})}$$

$$Ratio = 0.94696$$

Status: PASS
Ratio: 0.950

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.428\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.27675\ \text{kip/ft}^2$$

$q = 0.27675\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.27675\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.13837$$

Status: **PASS**
Ratio: **0.140**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.4375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.20159\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.8412\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.8412\ \text{kipft/ft}) \times (5.75\ \text{ft})) + \left(3 \times (-0.20159\ \text{kip/ft}) \times (5.75\ \text{ft})^2\right)}{(6 \times (2.8412\ \text{kipft/ft})) + (4 \times (-0.20159\ \text{kip/ft}) \times (5.75\ \text{ft}))}$$

$$a = 3.9358\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.8412\ \text{kipft/ft})) + (3 \times (-0.20159\ \text{kip/ft}) \times (5.75\ \text{ft}))]^2}{(5.75\ \text{ft})^2 \times [(3 \times (2.8412\ \text{kipft/ft})) + (2 \times (-0.20159\ \text{kip/ft}) \times (5.75\ \text{ft}))]}$$

$$p = 0.22742\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.8412\ \text{kipft/ft})) + ((-0.20159\ \text{kip/ft}) \times (5.75\ \text{ft}))]}{(5.75\ \text{ft})^2}$$

$$s = 0.82087\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.9358\ \text{ft})}{2}$$

$$p_a = 0.29518\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22742\ \text{kip/ft}^2\right)}{\left(0.29518\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.77044$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.82087\ \mathrm{kip/ft^2}\right)}{\left(0.8625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95173$$

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

Considering z-direction:

$H_o = -0.036146\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.15748\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15748\ \mathrm{kipft/ft}) \times (5.75\ \mathrm{ft})) + \left(3 \times (-0.036146\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft})^2\right)}{(6 \times (0.15748\ \mathrm{kipft/ft})) + (4 \times (-0.036146\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))}$$

$$a = 4.0576\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.15748\ \mathrm{kipft/ft})) + (3 \times (-0.036146\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]^{\,2}}{(5.75\ \mathrm{ft})^2 \times [(3 \times (0.15748\ \mathrm{kipft/ft})) + (2 \times (-0.036146\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}$$

$$p = 0.000016415\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.15748\ \mathrm{kipft/ft})) + ((-0.036146\ \mathrm{kip/ft}) \times (5.75\ \mathrm{ft}))]}{(5.75\ \mathrm{ft})^2}$$

$$s = 0.019441\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.0576\ \mathrm{ft})}{2}$$

$$p_a = 0.30432\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000016415\ \mathrm{kip/ft^2}\right)}{\left(0.30432\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00005394$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.75\ \mathrm{ft})$$

$$p_s = 0.8625\ \mathrm{kip/ft^2}$$

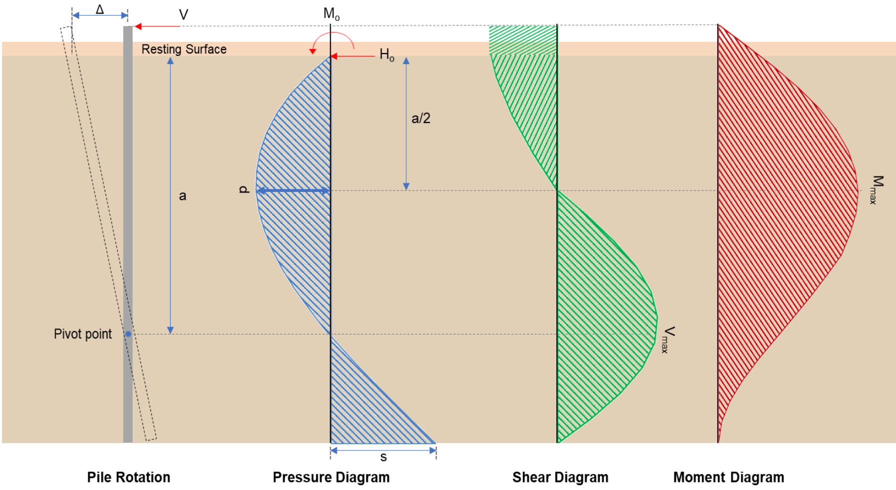
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.019441 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$Ratio = 0.02254$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.123 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.33806 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.337 \text{ kipft}) + ((-2.123 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.8307 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.8307 \text{ kipft/ft})}{(-0.33806 \text{ kip/ft})}$$

$$E = 14.29 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.8307 \text{ kipft/ft}) \times (5.75 \text{ ft})) + \left(3 \times (-0.33806 \text{ kip/ft}) \times (5.75 \text{ ft})^2\right)}{(6 \times (4.8307 \text{ kipft/ft})) + (4 \times (-0.33806 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9347 \text{ ft}$$

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

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

$$V_{max} = ((-0.33806 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.29 \text{ ft})}{(5.75 \text{ ft})} + 3\right) \times \left(\frac{(3.9347 \text{ ft})}{(5.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.29 \text{ ft})}{(5.75 \text{ ft})} + 2\right) \times \left(\frac{(3.9347 \text{ ft})}{(5.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.8417 \text{ kip}$$

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

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

$$M_{max} = ((-0.33806 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[\left(\frac{(14.29 \text{ ft})}{(5.75 \text{ ft})} + \frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.29 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.29 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(3.9347 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 18.961 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.347 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.055255 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.494 \text{ kipft}) + ((-0.347 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.2379 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2379 \text{ kipft/ft})}{(-0.055255 \text{ kip/ft})}$$

$$E = 4.3055 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2379 \text{ kipft/ft}) \times (5.75 \text{ ft})) + \left(3 \times (-0.055255 \text{ kip/ft}) \times (5.75 \text{ ft})^2\right)}{(6 \times (0.2379 \text{ kipft/ft})) + (4 \times (-0.055255 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.059 \text{ ft}$$

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

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

$$V_{max} = ((-0.055255 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.3055 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.059 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.3055 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.059 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.43927 \text{ kip}$$

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

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

$$M_{max} = ((-0.055255 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[\left(\frac{(4.3055 \text{ ft})}{(5.75 \text{ ft})} + \frac{(4.059 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.3055 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left(\frac{(4.059 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.3055 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left(\frac{(4.059 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.1489 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.874 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.368 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.368 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.874\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0025695$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 6.874\ \text{kip} \rightarrow 6874\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(6874\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.4\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.4\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.4\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.4 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.69 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.8417 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.8417 \text{ kip})}{(110.69 \text{ kip})}$$

$$Ratio = 0.061808$$

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

Considering z-direction:

$V_{max} = 0.43927 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.43927 \text{ kip})}{(110.69 \text{ kip})}$$

$$Ratio = 0.0039684$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 18.961\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(18.961\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.075964$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $M_{max} = 1.1489\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1489\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.0046029$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

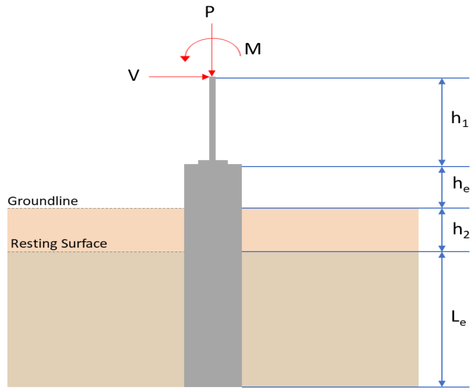
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.670	8.856
V_x (kip)	-1.558	-2.601
V_z (kip)	-0.020	-0.035
M_x (kipft)	-0.091	-0.160
M_z (kipft)	22.117	38.153

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.558\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.24809\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.117\ \text{kipft}) + ((-1.558\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.5218\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.8026\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.02\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0031847\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.091\ \text{kipft}) + ((-0.02\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.01449\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.99\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8026\ \text{ft}), (0.99\ \text{ft})]$$

$$L_{e,req} = 5.803\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.803\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.92848$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.67\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.35438\ \text{kip/ft}^2$$

$q = 0.35438\ \mathrm{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.35438\ \mathrm{kip/ft}^2\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.17719$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.24809\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.5218\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.5218\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.24809\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (3.5218\ \mathrm{kipft/ft})) + (4 \times (-0.24809\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2849\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.5218\ \mathrm{kipft/ft})) + (3 \times (-0.24809\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^{\,2}}{(6.25\ \mathrm{ft})^2 \times [(3 \times (3.5218\ \mathrm{kipft/ft})) + (2 \times (-0.24809\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.22901\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.5218\ \mathrm{kipft/ft})) + ((-0.24809\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.84374\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.2849\ \mathrm{ft})}{2}$$

$$p_a = 0.32136\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22901\ \mathrm{kip/ft}^2\right)}{\left(0.32136\ \mathrm{kip/ft}^2\right)}$$

$$Ratio = 0.71261$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.84374\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9$$

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

Considering z-direction:

$H_o = -0.0031847\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.01449\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.01449\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.01449\ \mathrm{kipft/ft})) + (4 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4156\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.01449\ \mathrm{kipft/ft})) + (3 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.01449\ \mathrm{kipft/ft})) + (2 \times (-0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.000016084\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.01449\ \mathrm{kipft/ft})) + ((-0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.0013941\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4156\ \mathrm{ft})}{2}$$

$$p_a = 0.33117\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000016084\ \mathrm{kip/ft^2}\right)}{\left(0.33117\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000048567$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

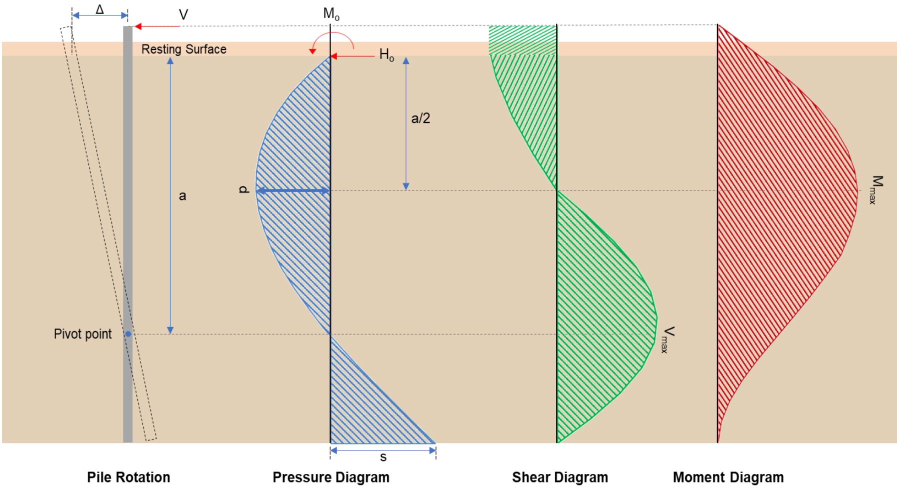
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0013941\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0014871$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.601\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.41417\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.153\ \mathrm{kipft}) + ((-2.601\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.0753\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.0753\ \mathrm{kipft/ft})}{(-0.41417\ \mathrm{kip/ft})}$$

$$E = 14.669\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.0753\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.41417\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (6.0753\ \mathrm{kipft/ft})) + (4 \times (-0.41417\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2819\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.41417\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.669\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2819\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.669\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2819\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.976\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.41417 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(14.669 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.2819 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.669 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.2819 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.669 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.2819 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 23.981 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.035 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0055732 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.16 \text{ kipft}) + ((-0.035 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.025478 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.025478 \text{ kipft/ft})}{(-0.0055732 \text{ kip/ft})}$$

$$E = 4.5714 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.025478 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.0055732 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (0.025478 \text{ kipft/ft})) + (4 \times (-0.0055732 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.415 \text{ ft}$$

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

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

$$V_{max} = ((-0.0055732 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5714 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.415 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.5714 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.415 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.043627 \text{ kip}$$

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

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

$$M_{max} = ((-0.0055732 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[\left(\frac{(4.5714 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.415 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.5714 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left(\frac{(4.415 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.5714 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left(\frac{(4.415 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.12384 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.856 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.302 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.302 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(8.856\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0033104$$	Status: **PASS** Ratio: **0.000**

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 8.856\ \text{kip} \rightarrow 8856\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(8856\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.67\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.67\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.67\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.67\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.86\ \text{kip}$$

Considering x-direction:

$V_{max} = 7.976\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.976\ \text{kip})}{(110.86\ \text{kip})}$$

$$Ratio = 0.071944$$

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

Considering z-direction:

$V_{max} = 0.043627\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.043627\ \text{kip})}{(110.86\ \text{kip})}$$

$$Ratio = 0.00039351$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 23.981 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(23.981 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.096079$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 0.12384 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.12384 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00049615$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

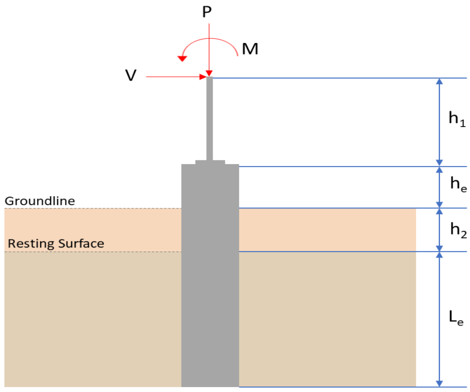
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.670	8.855
V_x (kip)	-1.558	-2.600
V_z (kip)	0.020	0.035
M_x (kipft)	0.090	0.160
M_z (kipft)	22.118	38.148

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.558\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.24809\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.118\ \text{kipft}) + ((-1.558\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.522\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.8027\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.02\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0031847\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.09\ \text{kipft}) + ((0.02\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.014331\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.1073\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.8027\ \text{ft}), (1.1073\ \text{ft})]$$

$$L_{e,req} = 5.803\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.803\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.92848$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.67\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.35438\ \text{kip/ft}^2$$

$q = 0.35438\ \text{kip/ft}$

	Check bearing capacity ratio: $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.35438\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$ $$Ratio = 0.17719$$		Status: **PASS** Ratio: **0.180**
Czerniak	**Lateral Soil Pressure (ASD):**		

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.24809\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.522\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.522\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.24809\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (3.522\ \text{kipft/ft})) + (4 \times (-0.24809\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.2848\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.522\ \text{kipft/ft})) + (3 \times (-0.24809\ \text{kip/ft}) \times (6.25\ \text{ft}))]^{\ 2}}{(6.25\ \text{ft})^2 \times [(3 \times (3.522\ \text{kipft/ft})) + (2 \times (-0.24809\ \text{kip/ft}) \times (6.25\ \text{ft}))]}$$

$$p = 0.22902\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.522\ \text{kipft/ft})) + ((-0.24809\ \text{kip/ft}) \times (6.25\ \text{ft}))]}{(6.25\ \text{ft})^2}$$

$$s = 0.84378\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.2848\ \text{ft})}{2}$$

$$p_a = 0.32136\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.22902\ \text{kip/ft}^2)}{(0.32136\ \text{kip/ft}^2)}$$

$$Ratio = 0.71266$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.84378\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.90004$$

Status: PASS
Ratio: 0.900

Considering z-direction:

$H_o = 0.0031847\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.014331\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.014331\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.014331\ \mathrm{kipft/ft})) + (4 \times (0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4171\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.014331\ \mathrm{kipft/ft})) + (3 \times (0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^{\ 2}}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.014331\ \mathrm{kipft/ft})) + (2 \times (0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.0031762\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.014331\ \mathrm{kipft/ft})) + ((0.0031847\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.0074599\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4171\ \mathrm{ft})}{2}$$

$$p_a = 0.33128\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0031762\ \mathrm{kip/ft^2})}{(0.33128\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0095878$$

Status: PASS
Ratio: 0.010

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

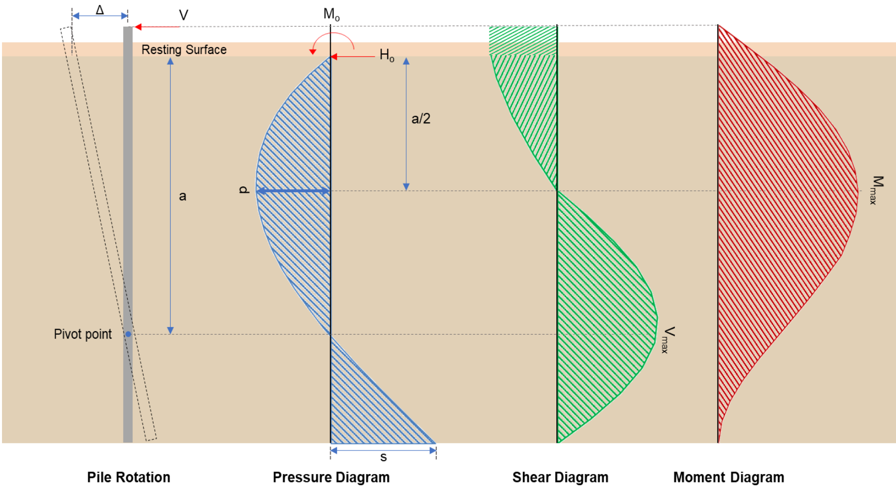
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0074599\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0079572$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.6\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.41401\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.148\ \mathrm{kipft}) + ((-2.6\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.0745\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.0745\ \mathrm{kipft/ft})}{(-0.41401\ \mathrm{kip/ft})}$$

$$E = 14.672\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.0745\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.41401\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (6.0745\ \mathrm{kipft/ft})) + (4 \times (-0.41401\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2819\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.41401\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.672\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2819\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.672\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2819\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.9747\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.41401\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(14.672\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.2819\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.672\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.2819\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.672\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.2819\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 23.978\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.035\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0055732\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.16\ \text{kipft}) + ((0.035\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.025478\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.025478\ \text{kipft/ft})}{(0.0055732\ \text{kip/ft})}$$

$$E = 4.5714\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.025478\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.025478\ \text{kipft/ft})) + (4 \times (0.0055732\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.415\ \text{ft}$$

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

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

$$V_{max} = ((0.0055732\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5714\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.415\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5714\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.415\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.043627\ \text{kip}$$

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

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

$$M_{max} = ((0.0055732\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(4.5714\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.415\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.5714\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.415\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5714\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.415\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12384 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.855 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.302 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.302 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.855\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0033101$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 8.855\text{ kip} \rightarrow 8855\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(8855\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 119.67\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (119.67\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 119.67\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.67 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.86 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.9747 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.9747 \text{ kip})}{(110.86 \text{ kip})}$$

$$Ratio = 0.071932$$

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

Considering z-direction:

$V_{max} = 0.043627 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.043627 \text{ kip})}{(110.86 \text{ kip})}$$

$$Ratio = 0.00039351$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 23.978\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(23.978\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.096064$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 0.12384\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.12384\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00049615$$	Status: **PASS** Ratio: **0.000**