# Your Project Calculations

Project Name: OrlandoProject-JB-RevB

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=OrlandoProject-JB-RevB&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/7_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=FLAZEujAORloOKHiuyejQW4AYxAkHRVvTBxqpMAHXjhpcTr5cBShAHrxHImBKt8s

### Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 2P-22.5-10TOP-HD-57-L-4Hx5W-2HB9 |
| **Duty Classification:** | HD |
| **Module Width:** | 44.70 in |
| **Module Length:** | 95.10in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 5 |
| **Total Number of Modules:** | 20 |
| **Desired Tilt Angle:** | 46 |
| **Front Edge Clearance:** | 9 |
| **Total Array Height at Tilt:** | 19.78 ft |
| **Total Frame Length:** | 39.50 ft |
| **Frame Weight:** | 2388 lbs |
| **Array Dimensions N/S:** | 15.07 ft |
| **Array Dimensions E/W:** | 40.04 ft |
| **Rail Length:** | 180.80 in |
| **Rail Spacing:** | 4.00 ft |
| **Rail Check:** | PASS (74% utilized) |

### Support Specifications

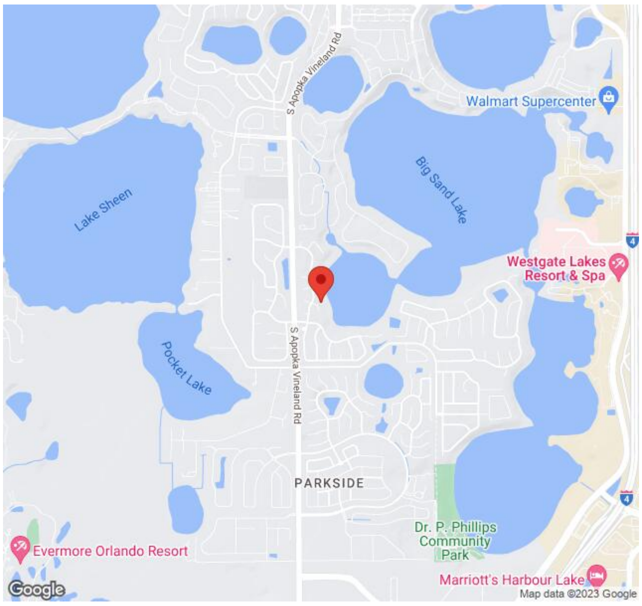
| | |
|---|---|
| **Pole Size:** | 10in Pipe Sch 40 |
| **Pole Length above Grade:** | 14.42 ft |
| **Number of Poles:** | 2 |
| **Pole Spacing:** | 22.5 ft |

### Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 8.75 ft<br>Pile 2: 8.75 ft |
| **Foundation Volume:** | 10.370 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 1.198958 kip |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 8633 Vista Shores Ct, Orlando, FL 32836, USA |
| **Wind Speed:** | 135 mph |
| **Snow Load:** | 0 psf |
| **Design Uplift Pressure:** | 0.037539 ksf |
| **Design Downforce Pressure:** | -0.037539 ksf |
| **Design Snow Pressure:** | 0.000000 ksf |




### Design Disclaimer

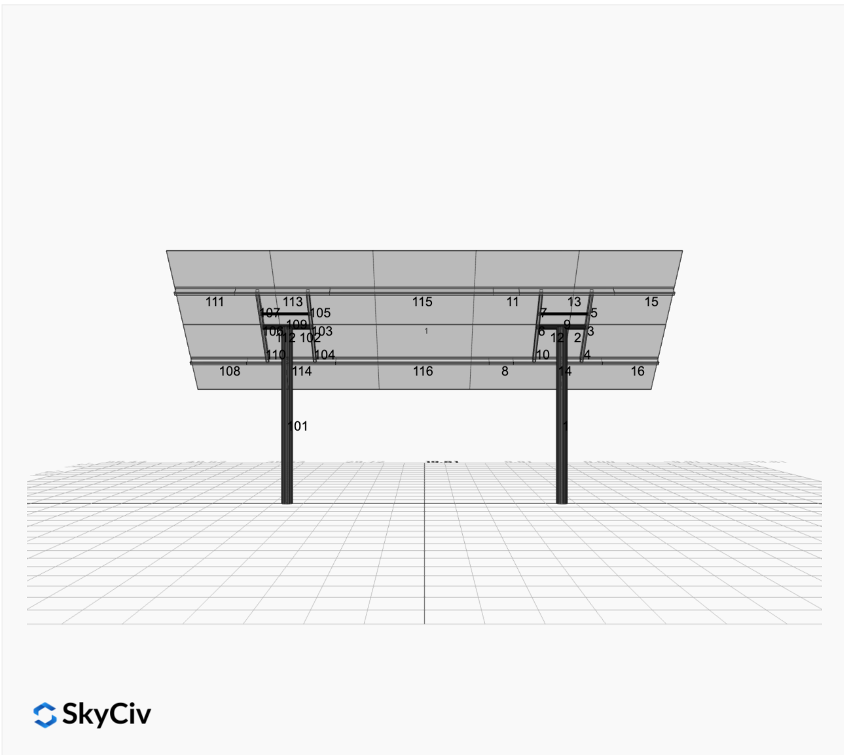
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

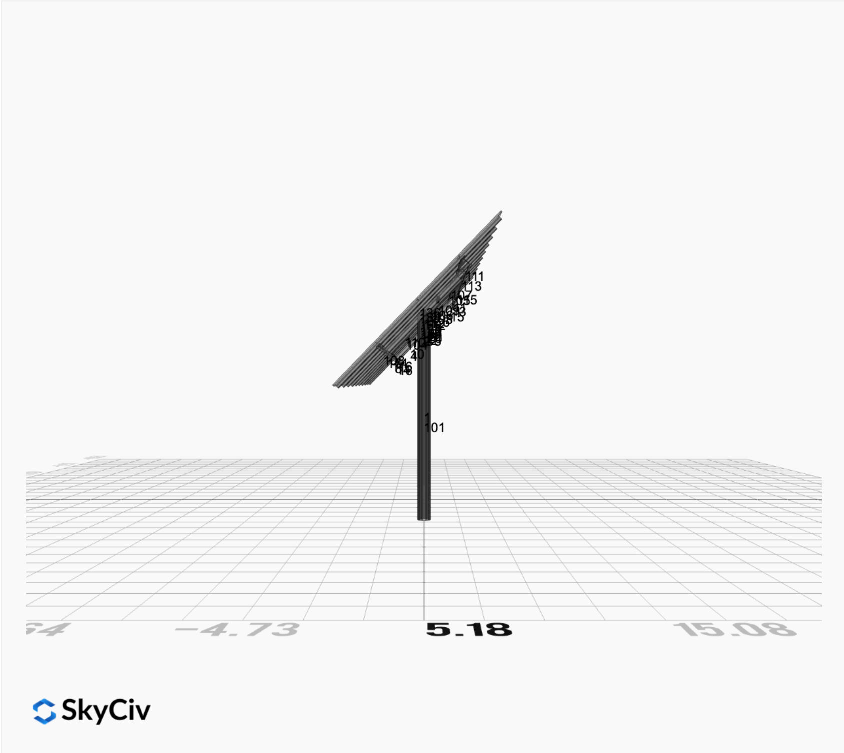
### AutoDesigner Input

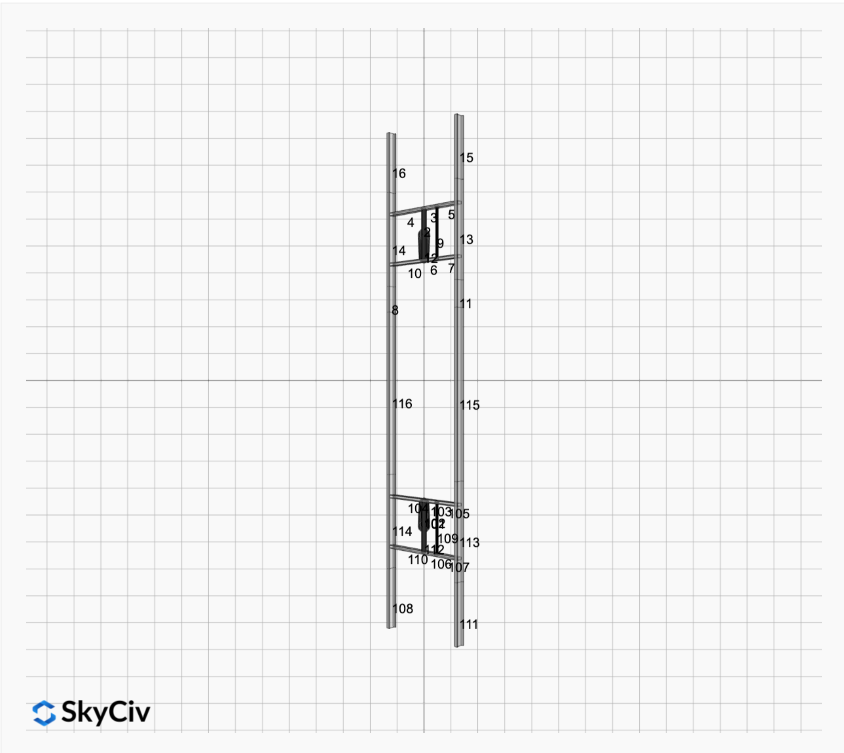
{"wind_speed_override":135,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"OrlandoProject-JB-RevB","site_address":"8633 Vista Shores Ct, Orlando, FL 32836, USA","module_width":44.7,"module_length":95.1,"number_rows":"4","number_columns":5,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":46,"ground_clearance":9,"risk_category":"I","exposure_category":"C","frame_duty_override":"HD","pole_override":"10_40","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":true}

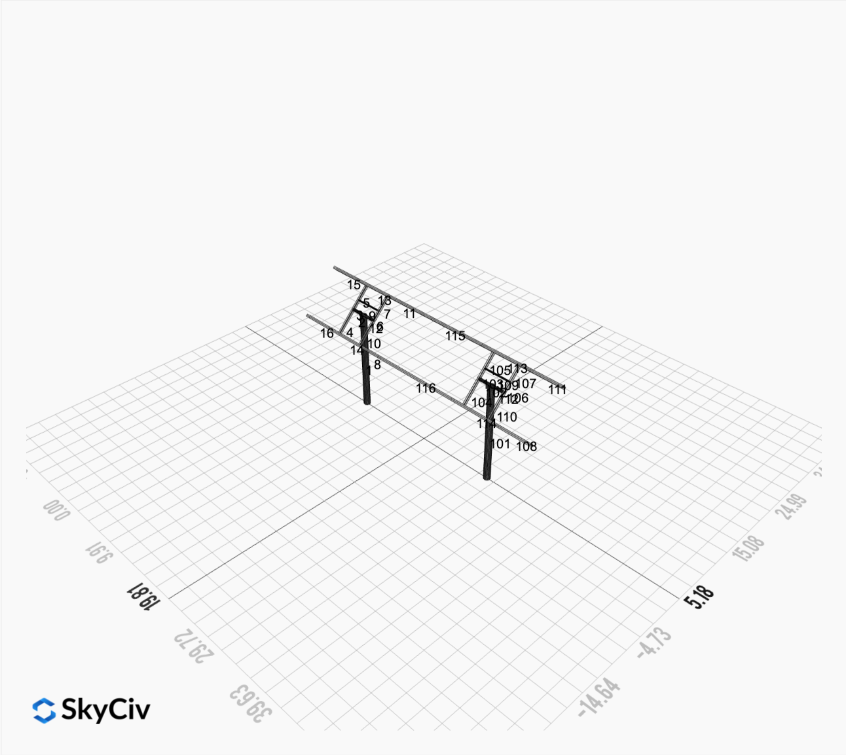
**Design Notes:**

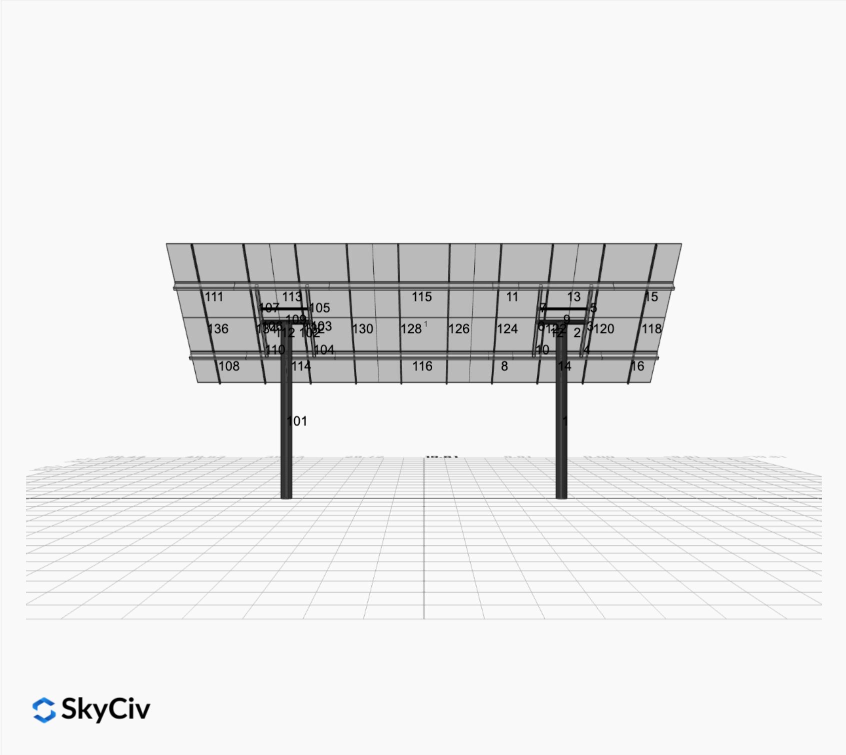
- AISC Deflection checks are set to L/1 due to structure design intent




-4.73
5.18
15.08
SkyCiv

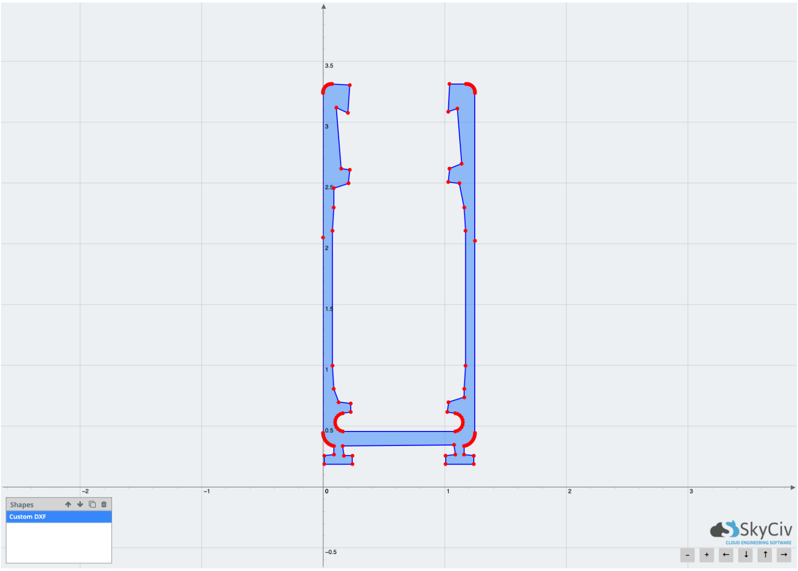

SkyCiv


SkyCiv
0.00
9.91
19.81
29.72
39.63
5.18
15.08
24.99
-4.73
-14.64
115
116
111
101
108

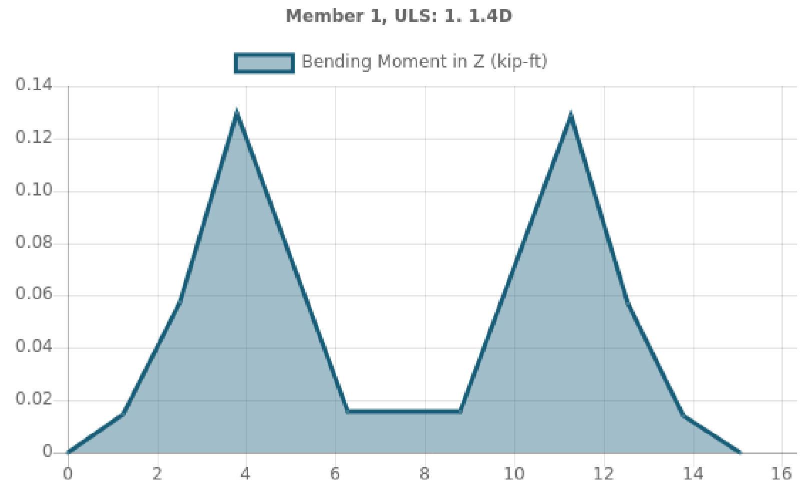

SkyCiv
111
113
115
11
13
136
130
128
126
124
120
118
108
114
116
8
101

## Rail Design Check

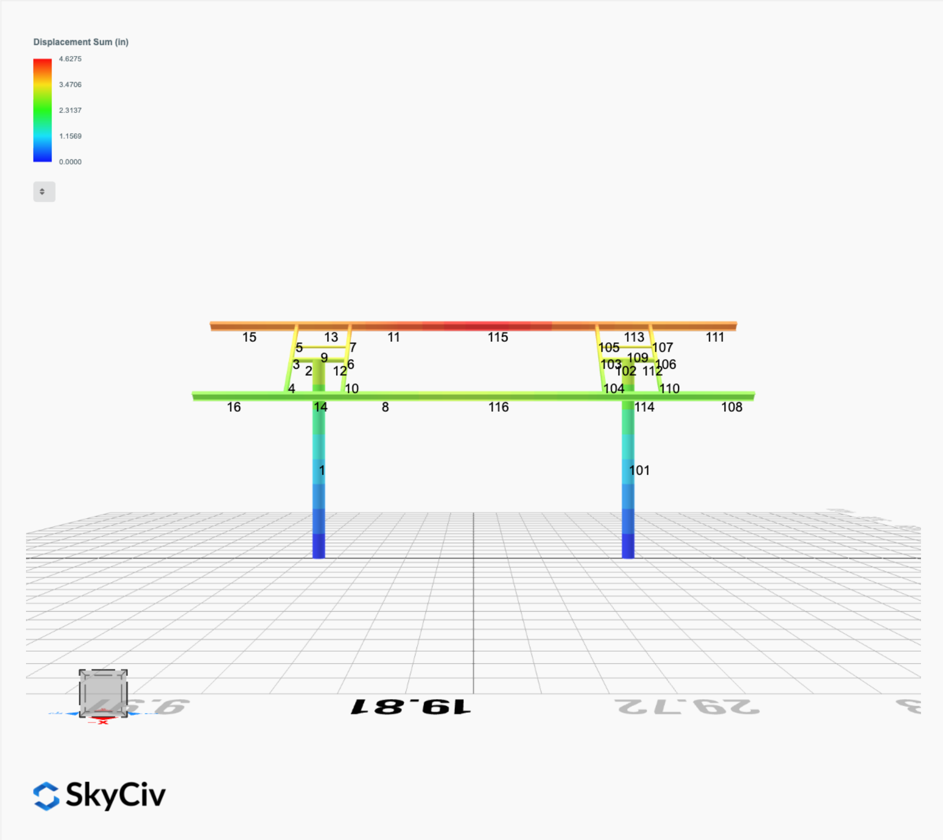
**Rail Length:** 15.066666666666668 ft
**Additional Restraints Required:** None
**Tributary Width:** 4.004166666666666 ft
**Material:** Aluminium
**Density:** 169 lb/ft$^3$
**Elasticity Modulus:** 10000 ksi
**Fy:** 34.5 ksi
**Fu:** 37 ksi
**Wind uplift Case A (X):** 0.0000 kip/ft
**Wind uplift Case A (Y):** 0.1503 kip/ft
**Wind downforce Case A:** -0.1503 kip/ft
**Dead (Panel load):** -0.1503 kip/ft

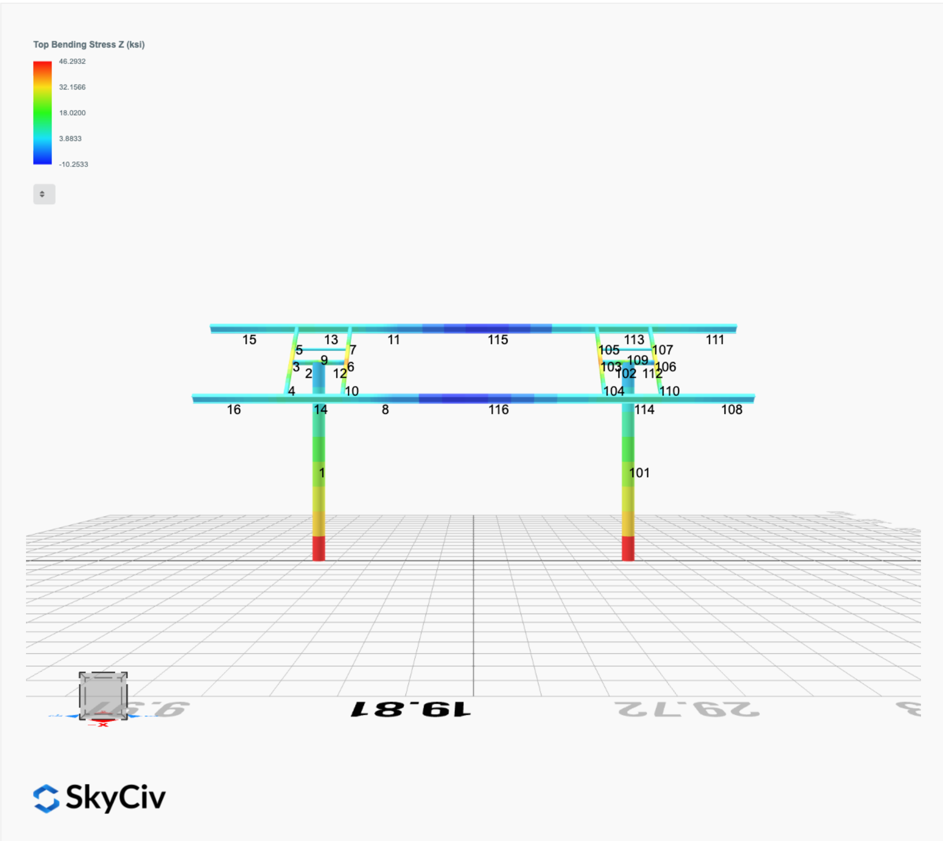


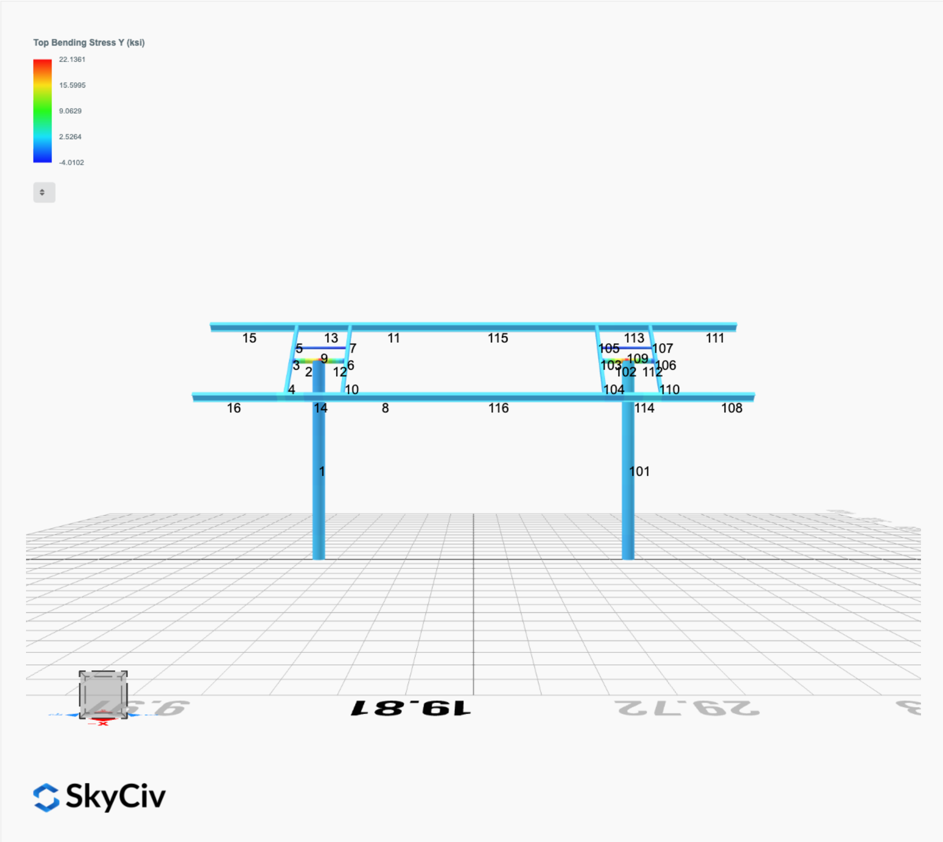

| Result Check | Max Limit | Max Value | Utility | Status |
|---|---|---|---|---|
| Custom Stress Limit | 34.5 | 25.66155165 | 0.744 | PASS |
| Material Yield | 34.5 | 25.66155165 | 0.744 | PASS |
| Material Strength | 37 | 25.66155165 | 0.694 | PASS |



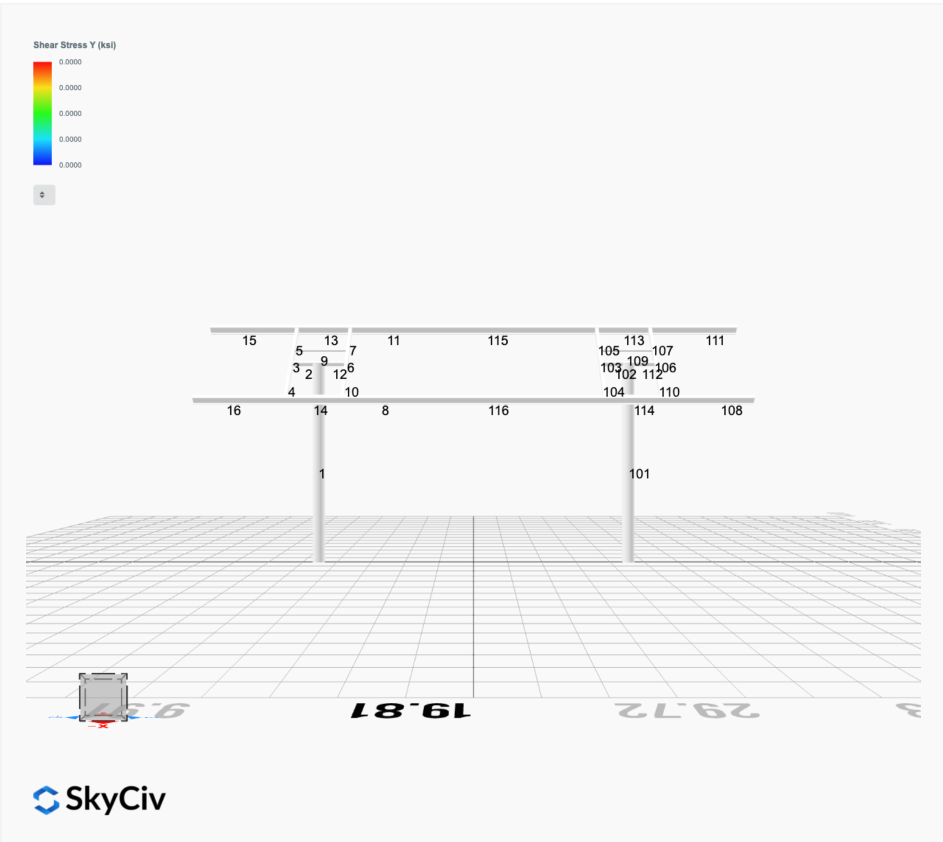
## FEM Results (Envelope Worst Case for each member)



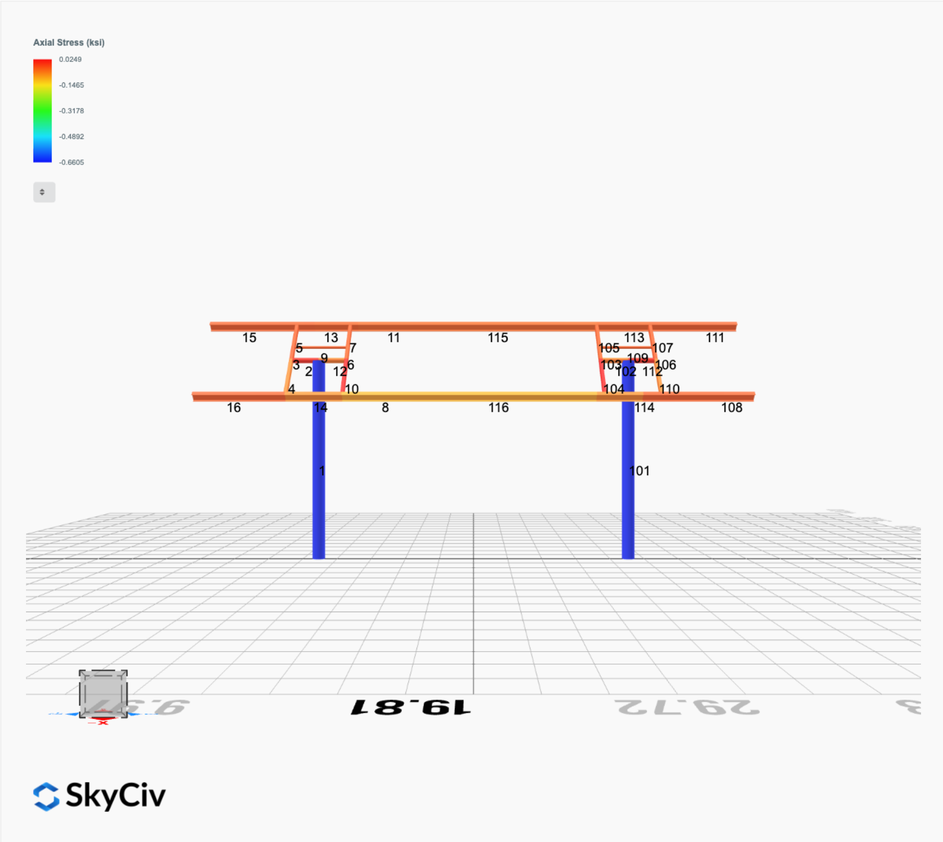





Top Bending Stress Y (ksi)
22.1361
15.5995
9.0629
2.5264
-4.0102
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
19.81
SkyCiv

Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
19.81
SkyCiv


Axial Stress (ksi)
0.0249
-0.1465
-0.3178
-0.4892
-0.6605
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
19.81
29.72
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 | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 2. D + L | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 5b. D + 0.7E | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 8. 0.6D + 0.7E | 0.0000 | 1.5303 | 0.0195 | 0.0843 | -0.0182 | 0.0135 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.8873 | 7.2701 | 0.1413 | 0.5767 | -0.7287 | 71.7040 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.8873 | -2.1691 | -0.0758 | -0.2923 | 0.6667 | -69.2841 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.6655 | 6.0902 | 0.1140 | 0.4677 | -0.5541 | 53.7836 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6655 | -0.9892 | -0.0487 | -0.1841 | 0.4924 | -51.9575 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.6655 | 6.0902 | 0.1140 | 0.4677 | -0.5541 | 53.7836 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6655 | -0.9892 | -0.0487 | -0.1841 | 0.4924 | -51.9575 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0000 | 2.5505 | 0.0324 | 0.1405 | -0.0304 | 0.0225 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.8873 | 6.2499 | 0.1283 | 0.5205 | -0.7165 | 71.6950 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0000 | 1.5303 | 0.0195 | 0.0843 | -0.0182 | 0.0135 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.8873 | -3.1893 | -0.0888 | -0.3485 | 0.6789 | -69.2931 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0000 | 1.5303 | 0.0195 | 0.0843 | -0.0182 | 0.0135 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 10.9266 |
| Shear X | -8.1455 |
| Shear Z | 0.2203 |
| Moment X | 0.8959 |
| Moment Y (Twist) | 1.1988 |
| Moment Z | 120.3561 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.2701 |
| Shear X | -4.8873 |
| Shear Z | 0.1413 |
| Moment X | 0.5767 |
| Moment Y (Twist) | 0.7287 |
| Moment Z | 71.7040 |

## 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 | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 2. D + L | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 5b. D + 0.7E | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.5303 | -0.0195 | -0.0843 | 0.0183 | 0.0135 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.8873 | 7.2701 | -0.1413 | -0.5767 | 0.7287 | 71.7040 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.8873 | -2.1691 | 0.0758 | 0.2922 | -0.6667 | -69.2841 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.6655 | 6.0902 | -0.1140 | -0.4677 | 0.5541 | 53.7836 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6655 | -0.9892 | 0.0487 | 0.1841 | -0.4924 | -51.9574 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.6655 | 6.0902 | -0.1140 | -0.4677 | 0.5541 | 53.7836 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6655 | -0.9892 | 0.0487 | 0.1841 | -0.4924 | -51.9574 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0000 | 2.5505 | -0.0324 | -0.1405 | 0.0304 | 0.0225 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.8873 | 6.2499 | -0.1283 | -0.5205 | 0.7165 | 71.6950 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0000 | 1.5303 | -0.0195 | -0.0843 | 0.0183 | 0.0135 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.8873 | -3.1893 | 0.0888 | 0.3485 | -0.6789 | -69.2931 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0000 | 1.5303 | -0.0195 | -0.0843 | 0.0183 | 0.0135 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 10.9266 |
| Shear X | -8.1455 |
| Shear Z | -0.2203 |
| Moment X | -0.8961 |
| Moment Y (Twist) | 1.1990 |
| Moment Z | 120.3574 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.2701 |
| Shear X | -4.8873 |
| Shear Z | -0.1413 |
| Moment X | -0.5767 |
| Moment Y (Twist) | 0.7287 |
| Moment Z | 71.7040 |

## Project Details

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

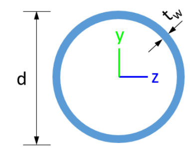
User Name: sales@mtsolar.us
Unit System: imperial

## Design Input Information

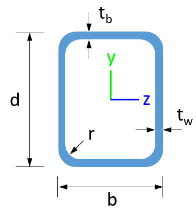
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

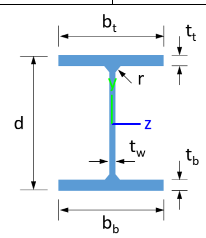
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | | |
| 11 | 10in Pipe Sch 40 | 10.75 | 0.36 | | | | | |




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




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

| Section Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | Name | A ($in^2$) | J ($in^4$) | $I_{yp}$ ($in^4$) | $I_{zp}$ ($in^4$) | $I_w$ ($in^6$) | $S_{yp}$ ($in^3$) | $S_{zp}$ ($in^3$) |
| 2 | 2in Pipe Sch 80 | 1.48 | 1.74 | 0.87 | 0.87 | 0.00 | 1.02 | 1.02 |
| 5 | 4in Pipe Sch 80 | 4.41 | 19.22 | 9.61 | 9.61 | 0.00 | 5.85 | 5.85 |
| 11 | 10in Pipe Sch 40 | 11.91 | 321.47 | 160.73 | 160.73 | 0.00 | 39.38 | 39.38 |

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

**Member Properties**

| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
|---|---|---|---|---|---|---|---|---|
| 1 | 11 | 30.28 | 30.28 | 14.42 | - | 300 | 200 | 1 |
| 2 | 5 | 2.00 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 2.10,2.10,2.10,2.10,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10,2.09,2.10 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 2.10,2.10,2.10,2.10,2.10,2.10,2.10,2.09,2.10,2.10,2.10,2.09,2.10,2.10,2.10,2.09,2.10,2.10,2.10,2.09,2.10,2.10,2.09,2.10 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08 | 300 | 200 | 1 |
| 15 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 101 | 11 | 30.28 | 30.28 | 14.42 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 108 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.69,1.69,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 111 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 112 | 5 | 2.00 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08 | 300 | 200 | 1 |
| 115 | 19 | 8.42 | 8.42 | 12.95 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 1 |
| 116 | 19 | 8.42 | 8.42 | 12.95 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 1 |

## Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|---|---|---|---|---|---|---|
| 1 | 535.87 | 262.09 | 147.68 | 147.68 | 160.76 | 160.76 |
| 2 | 198.33 | 194.54 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 535.87 | 262.09 | 147.68 | 147.68 | 160.76 | 160.76 |
| 102 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 104 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 105 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 106 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 107 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 108 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 109 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 110 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 111 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 194.54 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 46.28 | 12.35 | 6.12 | 40.24 | 43.62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 115 | 133.20 | 46.28 | 12.35 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 46.28 | 12.35 | 6.12 | 40.24 | 43.62 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.042 | 0.815 | 0.015 | 0.051 | 0.001 | 0.842 | #13 | 0.495 | Not Required | Pass |
| 2 | 0.002 | 0.348 | 0.321 | 0.078 | 0.065 | 0.669 | #13 | 0.054 | Not Required | Pass |
| 3 | 0.004 | 0.712 | 0.018 | 0.071 | 0.001 | 0.723 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.003 | 0.710 | 0.069 | 0.071 | 0.015 | 0.764 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.003 | 0.443 | 0.067 | 0.071 | 0.017 | 0.457 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.005 | 0.821 | 0.030 | 0.083 | 0.004 | 0.853 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.005 | 0.509 | 0.089 | 0.082 | 0.023 | 0.531 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.002 | 0.085 | 0.093 | 0.060 | 0.008 | 0.126 | #13 | 0.095 | Not Required | Pass |
| 9 | 0.007 | 0.068 | 0.080 | 0.002 | 0.002 | 0.151 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.005 | 0.818 | 0.084 | 0.082 | 0.018 | 0.850 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.001 | 0.084 | 0.095 | 0.060 | 0.008 | 0.130 | #13 | 0.095 | Not Required | Pass |
| 12 | 0.002 | 0.451 | 0.375 | 0.094 | 0.074 | 0.827 | #13 | 0.035 | Not Required | Pass |
| 13 | 0.003 | 0.302 | 0.202 | 0.074 | 0.009 | 0.430 | #13 | 0.286 | Not Required | Pass |
| 14 | 0.003 | 0.305 | 0.200 | 0.074 | 0.009 | 0.425 | #13 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.111 | 0.082 | 0.038 | 0.005 | 0.182 | #13 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.111 | 0.082 | 0.038 | 0.005 | 0.182 | #13 | Not Required | Not Required | Pass |
| 101 | 0.042 | 0.815 | 0.015 | 0.051 | 0.001 | 0.842 | #13 | 0.495 | Not Required | Pass |
| 102 | 0.002 | 0.451 | 0.375 | 0.094 | 0.074 | 0.827 | #13 | 0.035 | Not Required | Pass |
| 103 | 0.005 | 0.821 | 0.030 | 0.083 | 0.004 | 0.853 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.005 | 0.818 | 0.084 | 0.082 | 0.018 | 0.850 | #13 | 0.080 | Not Required | Pass |
| 105 | 0.005 | 0.509 | 0.089 | 0.082 | 0.023 | 0.531 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.004 | 0.712 | 0.018 | 0.071 | 0.001 | 0.723 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.003 | 0.443 | 0.067 | 0.071 | 0.017 | 0.457 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.000 | 0.111 | 0.082 | 0.038 | 0.005 | 0.182 | #13 | Not Required | Not Required | Pass |
| 109 | 0.007 | 0.068 | 0.080 | 0.002 | 0.002 | 0.151 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.003 | 0.710 | 0.069 | 0.071 | 0.015 | 0.764 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.000 | 0.111 | 0.082 | 0.038 | 0.005 | 0.182 | #13 | Not Required | Not Required | Pass |
| 112 | 0.002 | 0.348 | 0.321 | 0.078 | 0.065 | 0.669 | #13 | 0.054 | Not Required | Pass |
| 113 | 0.003 | 0.302 | 0.202 | 0.074 | 0.009 | 0.430 | #13 | 0.190 | Not Required | Pass |
| 114 | 0.003 | 0.305 | 0.200 | 0.074 | 0.009 | 0.425 | #13 | 0.286 | Not Required | Pass |
| 115 | 0.003 | 0.607 | 0.110 | 0.060 | 0.008 | 0.702 | #13 | 0.601 | Not Required | Pass |
| 116 | 0.002 | 0.610 | 0.110 | 0.060 | 0.008 | 0.707 | #13 | 0.601 | Not Required | Pass |

## Definitions

| | |
|---|---|
| $\Phi_t$ | Safety factor for tensile |
| $\Phi_c$ | Safety factor for compression |
| $\Phi_b$ | Safety factor for flexure |
| $\Phi_v$ | 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 |

| | |
|---|---|
| $L_b$ | Length between braced points |
| LST | Limited slenderness for tension |
| LSC | Limited slenderness for compression |
| LD | Limited deflection |
| $P_n$ | Nominal axial strength (tension/comression) |
| $M_n$ | Nominal flexural strength (about Z/Y axis) |
| $V_n$ | Nominal shear strength (along Z/Y axis) |
| P | Design ratio in case of axial force |
| $M_z$ | Design ratio in case of bending about Z axis |
| $M_y$ | Design ratio in case of bending about Y axis |
| $V_y$ | Design ratio in case of shear along Y axis |
| $V_z$ | Design ratio in case of shear along Z axis |
| $(P,M_z,M_y)$ | Design ratio in case of axial force and bending action |
| KL/r | Design ratio in case of section slenderness |
| δ | Design ratio in case of member deflection |
| OK | Capacity is provided |
| NG | Capacity is not provided |

| REFERENCES | CALCULATIONS | RESULTS |
|---|---|---|

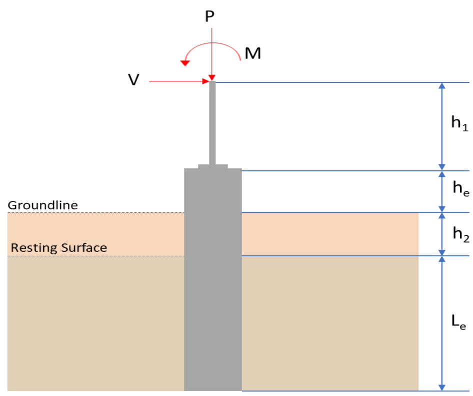
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 8.75\ \text{ft}$ - 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) | 7.270 | 10.927 |
| $V_x$ (kip) | -4.887 | -8.145 |
| $V_z$ (kip) | 0.141 | 0.220 |
| $M_x$ (kipft) | 0.577 | 0.896 |
| $M_z$ (kipft) | 71.704 | 120.356 |

**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,

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

$$H_o = \frac{(-4.887\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.77818\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(71.704 \text{ kipft}) + ((-4.887 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.418 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.1155 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.141 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.022452 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.577 \text{ kipft}) + ((0.141 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.091879 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.1743 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.1155 \text{ ft}), (2.1743 \text{ ft})]$$

$$L_{e,req} = 8.116 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.116 \text{ ft})}{(8.75 \text{ ft})}$$

$$Ratio = 0.92754$$

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

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

$$q = \frac{(7.27 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.45437 \text{ kip/ft}^2$$

$q = 0.45437\ \mathrm{kip/ft}^2$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.45437\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.22719$$

Status: **PASS**
Ratio: **0.230**

*Czerniak*

**Lateral Soil Pressure (ASD):**

$L/D$ - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.1875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.77818\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.418\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.418\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (11.418\ \mathrm{kipft/ft})) + (4 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.0408\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.418\ \mathrm{kipft/ft})) + (3 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (11.418\ \mathrm{kipft/ft})) + (2 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.30252\ \mathrm{kip/ft}^2$$

$s$ - Earth pressure against the pile at distance $L_e$,

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

$$s = \frac{6 \times [(2 \times (11.418\ \mathrm{kipft/ft})) + ((-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.256\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0408\ \mathrm{ft})}{2}$$

$$p_a = 0.45306\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.30252\ \mathrm{kip/ft}^2)}{(0.45306\ \mathrm{kip/ft}^2)}$$

$$Ratio = 0.66773$$

Status: **PASS**
Ratio: **0.670**

$p_s$ - Allowable lateral soil pressure at depth $L_e$,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.256\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95692$$

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

**Considering z-direction:**

$H_o = 0.022452\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.091879\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.091879\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.091879\ \mathrm{kipft/ft})) + (4 \times (0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.2619\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.091879\ \mathrm{kipft/ft})) + (3 \times (0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.091879\ \mathrm{kipft/ft})) + (2 \times (0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.013416\ \mathrm{kip/ft^2}$$

$s$ - Earth pressure against the pile at distance $L_e$,

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

$$s = \frac{6 \times [(2 \times (0.091879\ \mathrm{kipft/ft})) + ((0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 0.029796\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2619\ \mathrm{ft})}{2}$$

$$p_a = 0.46964\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.013416\ \mathrm{kip/ft^2}\right)}{\left(0.46964\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.028567$$

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

$p_s$ - Allowable lateral soil pressure at depth $L_e$,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

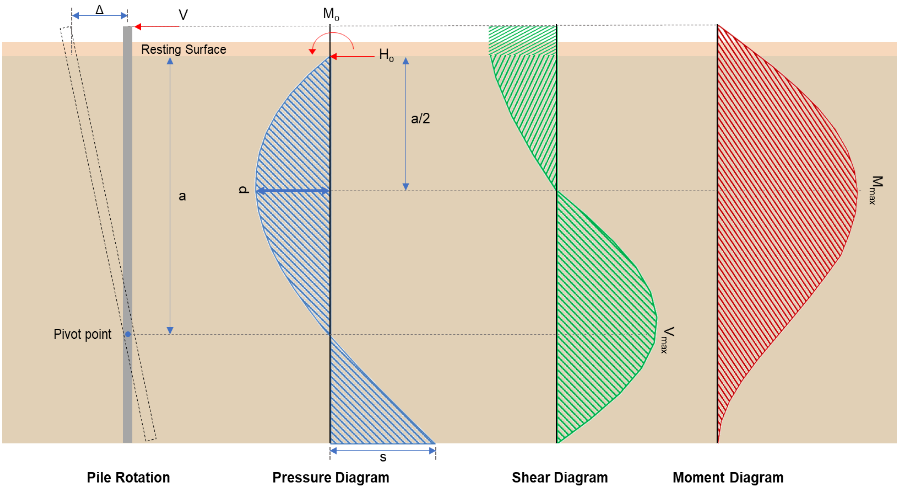
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.029796\ \text{kip/ft}^2)}{(1.3125\ \text{kip/ft}^2)}$$

$$Ratio = 0.022702$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-8.145\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.297\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(120.36\ \text{kipft}) + ((-8.145\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 19.165\ \text{kipft/ft}$$

$E$ - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.165\ \text{kipft/ft})}{(-1.297\ \text{kip/ft})}$$

$$E = 14.777\ \text{ft}$$

$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.165\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.297\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (19.165\ \text{kipft/ft})) + (4 \times (-1.297\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.0397\ \text{ft}$$

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

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

$$V_{max} = ((-1.297\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.777\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.0397\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.777\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.0397\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 18.924\ \text{kip}$$

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

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

$$M_{max} = ((-1.297 \text{ kip/ft}) \times (48 \text{ in}) \times (8.75 \text{ ft})) \times \left[ \left( \frac{(14.777 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.0397 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.777 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left( \frac{(6.0397 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (14.777 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left( \frac{(6.0397 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 78.674 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.22 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.035032 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.896 \text{ kipft}) + ((0.22 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.14268 \text{ kipft/ft}$$

$E$ - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.14268 \text{ kipft/ft})}{(0.035032 \text{ kip/ft})}$$

$$E = 4.0727 \text{ ft}$$

$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14268 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (0.035032 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.14268 \text{ kipft/ft})) + (4 \times (0.035032 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.2627 \text{ ft}$$

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

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

$$V_{max} = ((0.035032 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.0727 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left( \frac{(6.2627 \text{ ft})}{(8.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (4.0727 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left( \frac{(6.2627 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.20888 \text{ kip}$$

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

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

$$M_{max} = ((0.035032 \text{ kip/ft}) \times (48 \text{ in}) \times (8.75 \text{ ft})) \times \left[ \left( \frac{(4.0727 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.2627 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.0727 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left( \frac{(6.2627 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.0727 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left( \frac{(6.2627 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.80458 \text{ kipft}$$

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.927 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.233 \text{ in}^2$$

$A_{min}$ - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.233 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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* $\phi P_N$ - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.927\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0040846$$

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

**Shear Strength (ACI 318-19, LRFD)**

**Parameters:**

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

*22.5.2.2* $d$ - Effective depth

$$d = 0.80\, D$$

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

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

*22.5.5.1.3* $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 10.927\ \mathrm{kip} \rightarrow 10927\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(10927\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.94\ \mathrm{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.94\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.94\ \mathrm{kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.94\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.04\ \mathrm{kip}$$

**Considering x-direction:**

$V_{max} = 18.924\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(18.924\ \mathrm{kip})}{(111.04\ \mathrm{kip})}$$

$$Ratio = 0.17042$$

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

**Considering z-direction:**

$V_{max} = 0.20888\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.20888\ \mathrm{kip})}{(111.04\ \mathrm{kip})}$$

$$Ratio = 0.001881$$

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

**Flexural Strength (ACI 318-19, LRFD)**

$S_m$ - Section modulus

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

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

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

| | | |
|---|---|---|
| | $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 249.600kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2121.6\text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$<br>$$\phi M_n = 249.6\text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 78.674\text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(78.674\text{ kipft})}{(249.6\text{ kipft})}$$<br>$$Ratio = 0.3152$$ | Status: **PASS**<br>Ratio: **0.320** |
| | **Considering z-direction:**<br>$M_{max} = 0.80458\text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.80458\text{ kipft})}{(249.6\text{ kipft})}$$<br>$$Ratio = 0.0032235$$ | Status: **PASS**<br>Ratio: **0.000** |

| REFERENCES | CALCULATIONS | RESULTS |
|---|---|---|

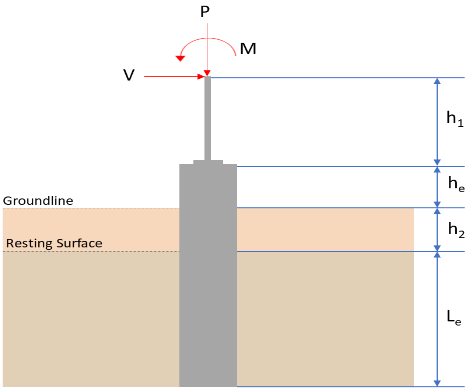
## SkyCiv Foundation Design

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
$L = 8.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.270 | 10.927 |
| $V_x$ (kip) | -4.887 | -8.145 |
| $V_z$ (kip) | -0.141 | -0.220 |
| $M_x$ (kipft) | -0.577 | -0.896 |
| $M_z$ (kipft) | 71.704 | 120.357 |

**Material Properties**

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

### Required depth to resist lateral loads (ASD)

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.887\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.77818\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(71.704\ \mathrm{kipft}) + ((-4.887\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.418\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.1155\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.141\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.022452\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.577\ \mathrm{kipft}) + ((-0.141\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.091879\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.7146\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.1155\ \mathrm{ft}), (1.7146\ \mathrm{ft})]$$

$$L_{e,req} = 8.116\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.75\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.116\ \mathrm{ft})}{(8.75\ \mathrm{ft})}$$

$$Ratio = 0.92754$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\,D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.27\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.45437\ \mathrm{kip/ft}^2$$

$q = 0.45437\ \mathrm{kip/ft^2}$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.45437\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.22719$$

Status: **PASS**
Ratio: **0.230**

*Czerniak*

**Lateral Soil Pressure (ASD):**

$L/D$ - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.1875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.77818\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.418\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.418\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (11.418\ \mathrm{kipft/ft})) + (4 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.0408\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.418\ \mathrm{kipft/ft})) + (3 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (11.418\ \mathrm{kipft/ft})) + (2 \times (-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.30252\ \mathrm{kip/ft^2}$$

$s$ - Earth pressure against the pile at distance $L_e$,

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

$$s = \frac{6 \times [(2 \times (11.418\ \mathrm{kipft/ft})) + ((-0.77818\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.256\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0408\ \mathrm{ft})}{2}$$

$$p_a = 0.45306\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.30252\ \mathrm{kip/ft^2}\right)}{\left(0.45306\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.66773$$

Status: **PASS**
Ratio: **0.670**

$p_s$ - Allowable lateral soil pressure at depth $L_e$,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.256\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95692$$

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

**Considering z-direction:**

$H_o = -0.022452\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.091879\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.091879\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.091879\ \mathrm{kipft/ft})) + (4 \times (-0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.2619\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.091879\ \mathrm{kipft/ft})) + (3 \times (-0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.091879\ \mathrm{kipft/ft})) + (2 \times (-0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = -0.0041112\ \mathrm{kip/ft^2}$$

$s$ - Earth pressure against the pile at distance $L_e$,

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

$$s = \frac{6 \times [(2 \times (0.091879\ \mathrm{kipft/ft})) + ((-0.022452\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = -0.0009952\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2619\ \mathrm{ft})}{2}$$

$$p_a = 0.46964\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0041112\ \mathrm{kip/ft^2}\right)}{\left(0.46964\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.008754$$

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

$p_s$ - Allowable lateral soil pressure at depth $L_e$,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

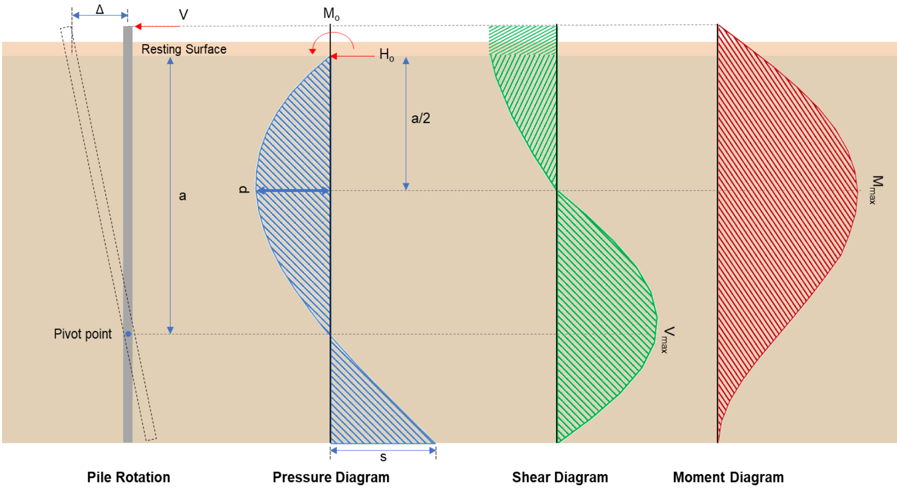
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0009952 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

$$Ratio = -0.00075824$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-8.145 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.297 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(120.36 \text{ kipft}) + ((-8.145 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 19.165 \text{ kipft/ft}$$

$E$ - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.165 \text{ kipft/ft})}{(-1.297 \text{ kip/ft})}$$

$$E = 14.777 \text{ ft}$$

$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.165 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-1.297 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (19.165 \text{ kipft/ft})) + (4 \times (-1.297 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0397 \text{ ft}$$

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

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

$$V_{max} = ((-1.297 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.777 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.0397 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.777 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.0397 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 18.924 \text{ kip}$$

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

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

$$M_{max} = ((-1.297\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.75\ \mathrm{ft})) \times \left[\left(\frac{(14.777\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + \frac{(6.0397\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.777\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.0397\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.777\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.0397\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 78.674\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.22\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.035032\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.896\ \mathrm{kipft}) + ((-0.22\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.14268\ \mathrm{kipft/ft}$$

$E$ - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.14268\ \mathrm{kipft/ft})}{(-0.035032\ \mathrm{kip/ft})}$$

$$E = 4.0727\ \mathrm{ft}$$

$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14268\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.035032\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.14268\ \mathrm{kipft/ft})) + (4 \times (-0.035032\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.2627\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.035032\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.0727\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.2627\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.0727\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.2627\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.20888\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.035032\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.75\ \mathrm{ft})) \times \left[\left(\frac{(4.0727\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + \frac{(6.2627\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (4.0727\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.2627\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.0727\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.2627\ \mathrm{ft})}{2 \times (8.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.80458 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 2.5$ ksi - Concrete strength,
$f_{yk} = 60$ ksi - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.8$ - 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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.927 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.233 \text{ in}^2$$

$A_{min}$ - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.233 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

$A_{st}$ - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

*25.2.3* $s_{rebar}$ - Minimum spacing of reinforcement,

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

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

| | | |
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| | **Axial Compression Strength (ACI 318-19, LRFD)** | |
| *22.4.2.2* | $\phi P_N$ - Allowable axial compressive strength<br>$$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$<br>$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$<br>$$\phi P_N = 2675.2\ \mathrm{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(10.927\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$<br>$$Ratio = 0.0040846$$ | Status: **PASS**<br>Ratio: **0.000** |

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| | **Shear Strength (ACI 318-19, LRFD)** | |
| | **Parameters:** | |
| | $b_w = 48\ \mathrm{in}$ - Effective width, | |
| *22.5.2.2* | $d$ - Effective depth<br>$$d = 0.80\ D$$<br>$$d = 0.80 \times (48\ \mathrm{in})$$<br>$$d = 38.4\ \mathrm{in}$$ | |
| *22.5.5.1.3* | $\lambda_s$ - size effect modification factor<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$<br>$$\lambda_s = 0.64282$$ | |
| | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, | |
| *22.5.5.1.1* | $V_{c,max}$ - Max shear strength of concrete<br>$$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$<br>$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,max} = 296.21\ \mathrm{kip}$$ | |
| | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 10.927\ \mathrm{kip} \rightarrow 10927\ \mathrm{lbf}$, | |
| *22.5.5.1.1(a)* | $V_{c,a}$ - Shear strength of concrete (a)<br>$$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$<br>$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(10927\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,a} = 119.94\ \mathrm{kip}$$ | |
| | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, | |
| *22.5.5.1.2* | $V_{c,b}$ - Shear strength of concrete (b)<br>$$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$<br>$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,b} = 348.89\ \mathrm{kip}$$ | |
| | $V_c$ - Governing shear strength of concrete<br>$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$<br>$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.94\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$<br>$$V_c = 119.94\ \mathrm{kip}$$ | |

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| | 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)<br>$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$<br>$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$<br>$$V_{s,a} = 737.28\ \text{kip}$$<br>$A_v$ - Ties rebar area,<br>$$A_v = \frac{\pi\, d_{ties}^2}{4}$$<br>$$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$<br>$$A_v = 0.11045\ \text{in}^2$$ | |
| 22.5.8.5.3 | $V_{s,b}$ - Shear strength of steel (b)<br>$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$<br>$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$<br>$$V_{s,b} = 50.894\ \text{kip}$$<br>$V_s$ - Governing shear strength of steel<br>$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$<br>$$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$<br>$$V_s = 50.894\ \text{kip}$$ | |
| 22.5.1.1 | $\phi V_n$ - Allowable shear strength<br>$$\phi V_n = \phi\ (V_c + V_s)$$<br>$$\phi V_n = (0.65) \times ((119.94\ \text{kip}) + (50.894\ \text{kip}))$$<br>$$\phi V_n = 111.04\ \text{kip}$$<br>**Considering x-direction:**<br>$V_{max} = 18.924\ \text{kip}$ - Maximum shear force in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{V_{max}}{\phi V_n}$$<br>$$Ratio = \frac{(18.924\ \text{kip})}{(111.04\ \text{kip})}$$<br>$$Ratio = 0.17042$$ | Status: **PASS**<br>Ratio: **0.170** |
| | **Considering z-direction:**<br>$V_{max} = 0.20888\ \text{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{V_{max}}{\phi V_n}$$<br>$$Ratio = \frac{(0.20888\ \text{kip})}{(111.04\ \text{kip})}$$<br>$$Ratio = 0.001881$$ | Status: **PASS**<br>Ratio: **0.000** |
| | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - Section modulus<br>$$S_m = \frac{b\, D^2}{6}$$<br>$$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$<br>$$S_m = 18432\ \text{in}^3$$ | |

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| | $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 249.600kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2121.6 \text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$<br>$$\phi M_n = 249.6 \text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 78.674 \text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(78.674 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.3152$$ | Status: **PASS**<br>Ratio: **0.320** |
| | **Considering z-direction:**<br>$M_{max} = 0.80458 \text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.80458 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.0032235$$ | Status: **PASS**<br>Ratio: **0.000** |