# Your Project Calculations

Project Name: MTSOLAR_Steinhagen_PNS360_rev2

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_Steinhagen_PNS360_rev2&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=Cb0xTdoUDD3Z5tRZ37qkF5wdI3D4RUPqSdtlo5DsRaXjl1YIJxwIxzcYXkcdPztT

### Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 2P-19.75-8TOP-HD-45-L-4Hx6W-J185 |
| **Duty Classification:** | HD |
| **Module Width:** | 40.94 in |
| **Module Length:** | 69.10in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 6 |
| **Total Number of Modules:** | 24 |
| **Desired Tilt Angle:** | 45 |
| **Front Edge Clearance:** | 3 |
| **Total Array Height at Tilt:** | 12.71 ft |
| **Total Frame Length:** | 34.75 ft |
| **Frame Weight:** | 1574 lbs |
| **Array Dimensions N/S:** | 13.81 ft |
| **Array Dimensions E/W:** | 35.05 ft |
| **Rail Length:** | 165.76 in |
| **Rail Spacing:** | 2.88 ft |
| **Rail Check:** | Not Checked |

### Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 40 |
| **Pole Length above Grade:** | 7.88 ft |
| **Number of Poles:** | 2 |
| **Pole Spacing:** | 19.75 ft |

### Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Round |
| **Foundation Dimensions:** | Ø36 in |
| **Foundation Depth (below grade):** | Pile 1: 8.75 ft<br>Pile 2: 8.75 ft |
| **Foundation Volume:** | 4.581 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.714174 kip |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | N8721 Carnot Dr, Algoma, WI 54201, USA |
| **Wind Speed:** | 100 mph |
| **Snow Load:** | 40 psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.010996 ksf |


### Design Disclaimer

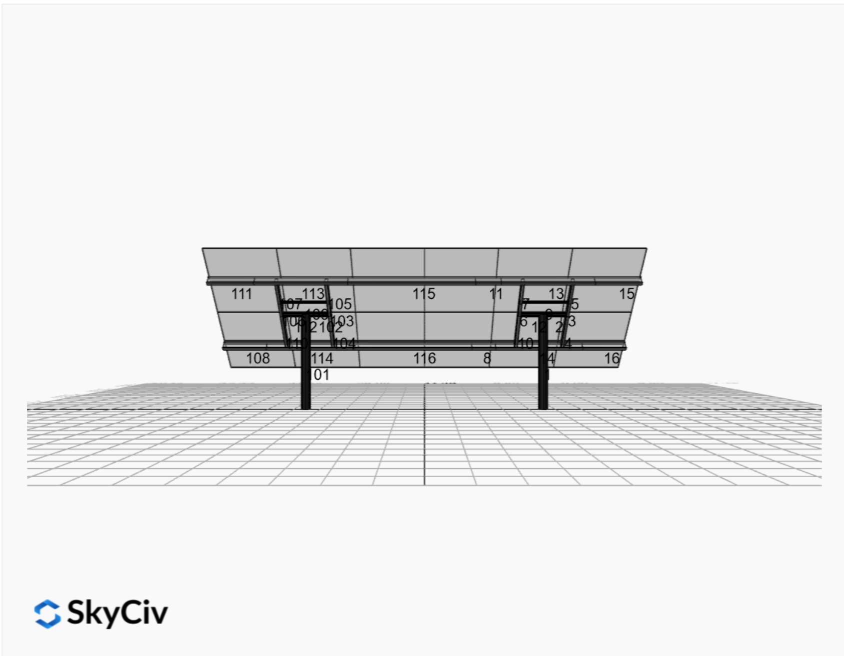
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

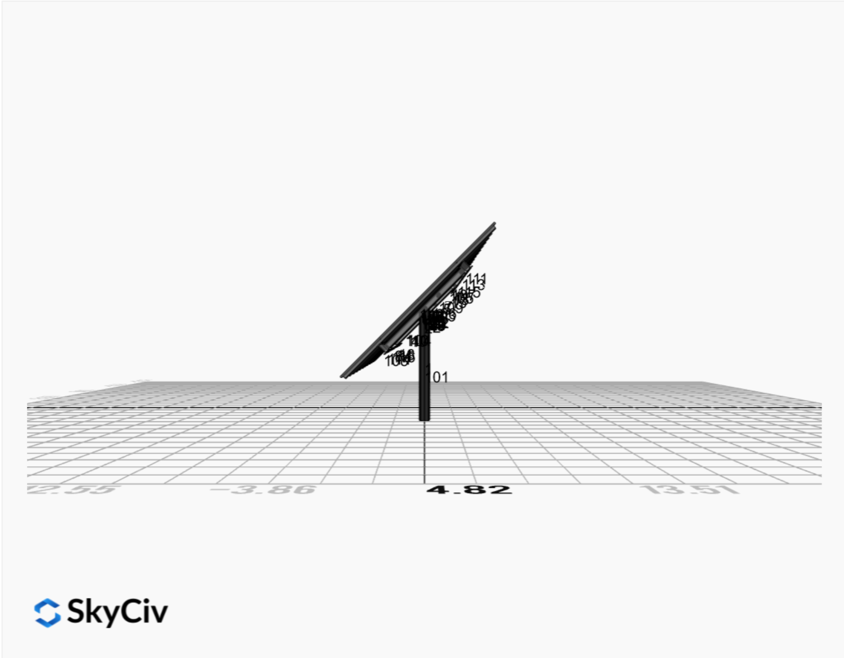
### AutoDesigner Input

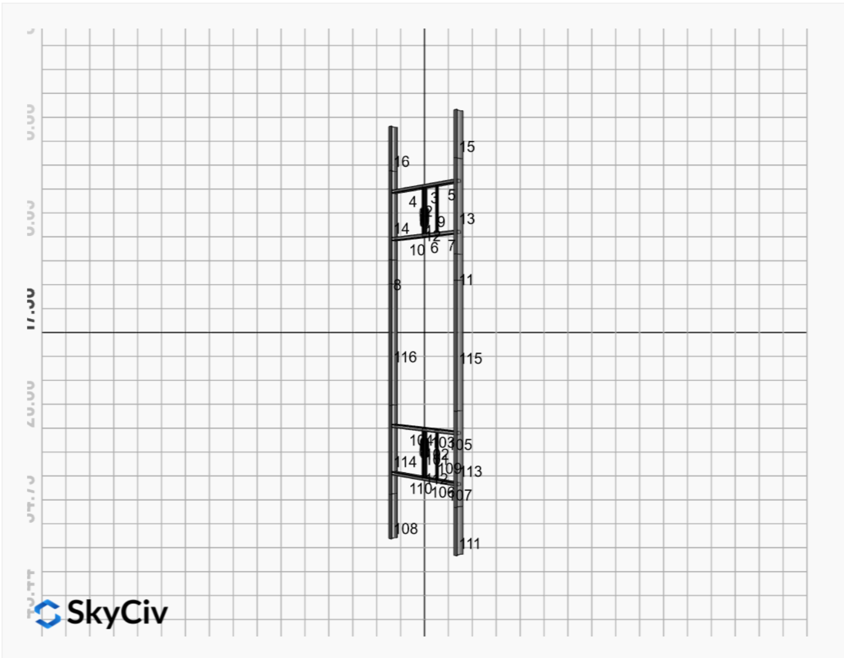
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_Steinhagen_PNS360_rev2","site_address":"N8721 Carnot Dr, Algoma, WI 54201, USA","module_width":40.94,"module_length":69.1,"number_rows":"4","number_columns":6,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":45,"ground_clearance":3,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false}

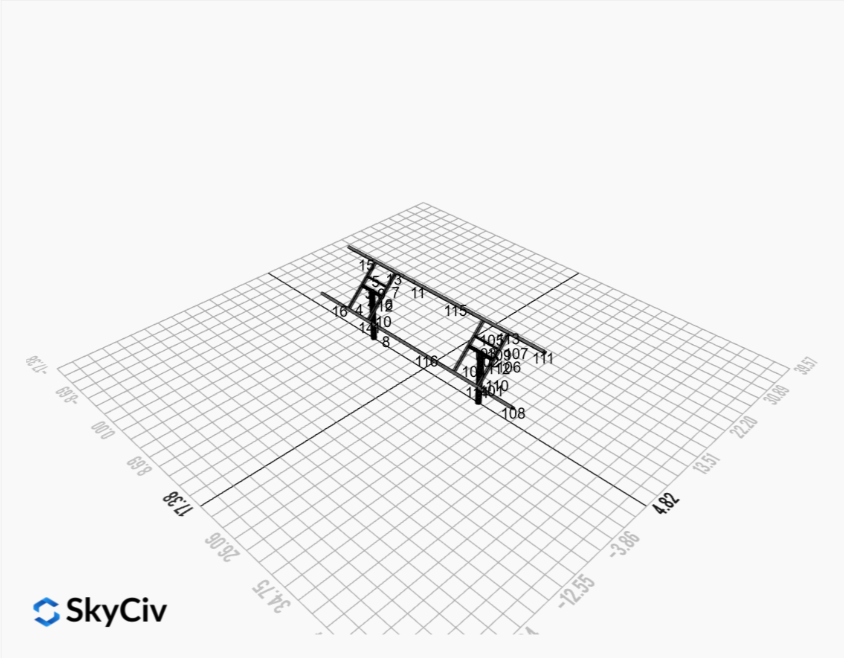
**Design Notes:**

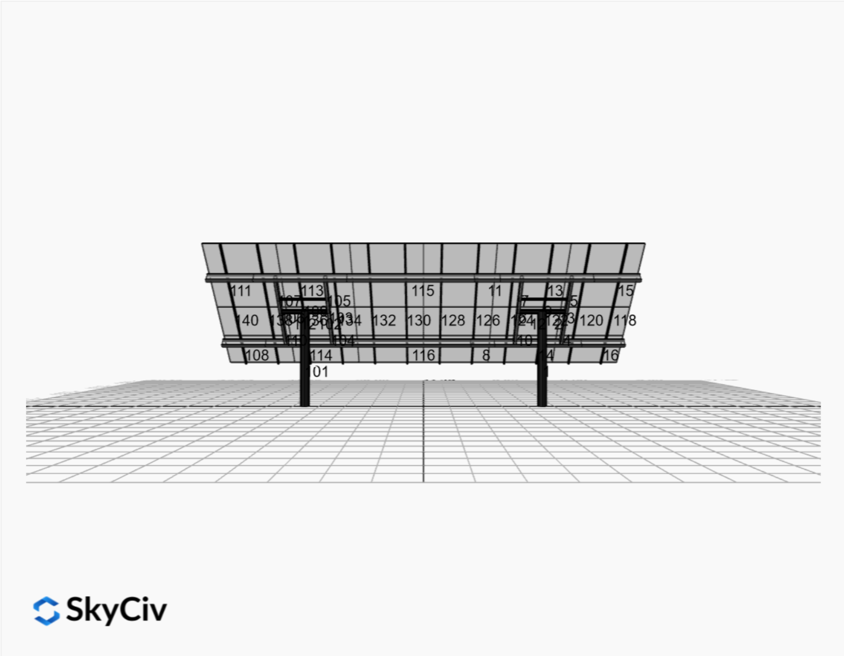
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



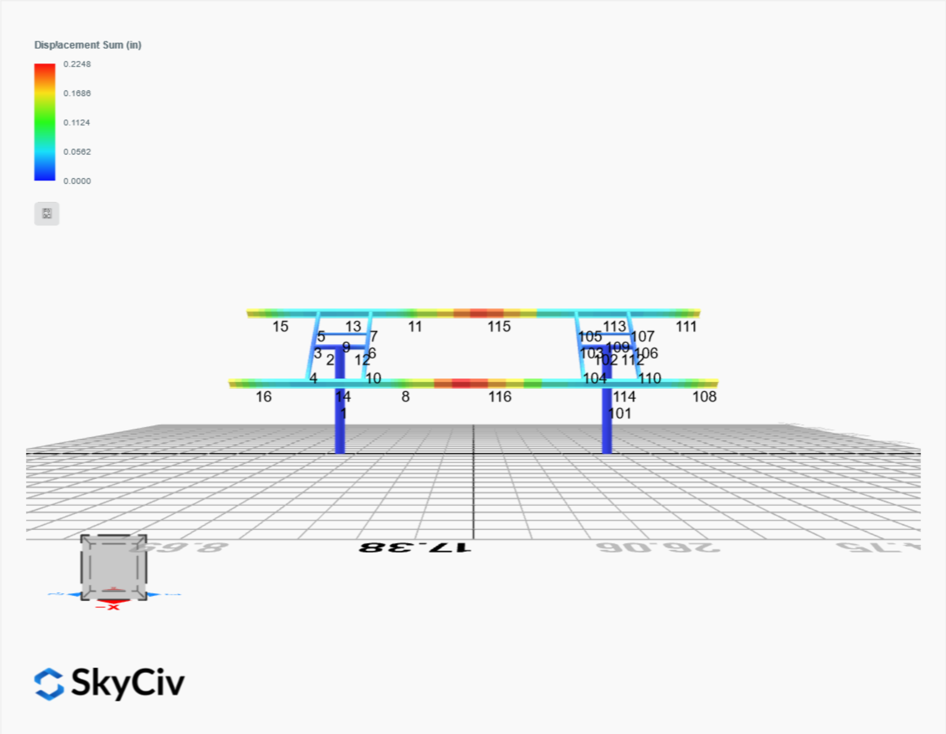


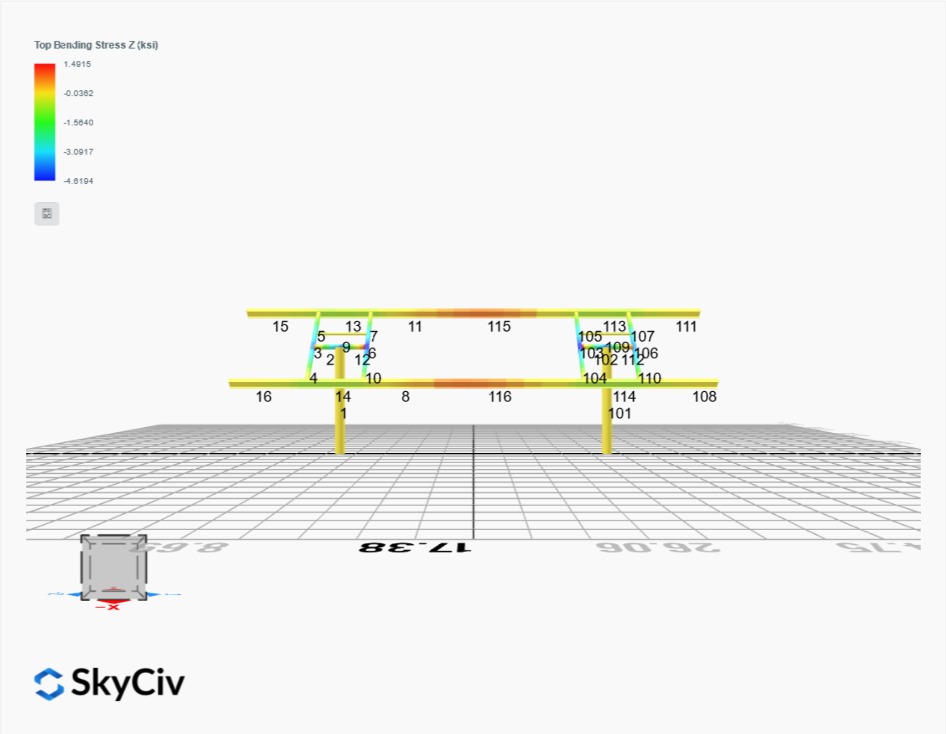


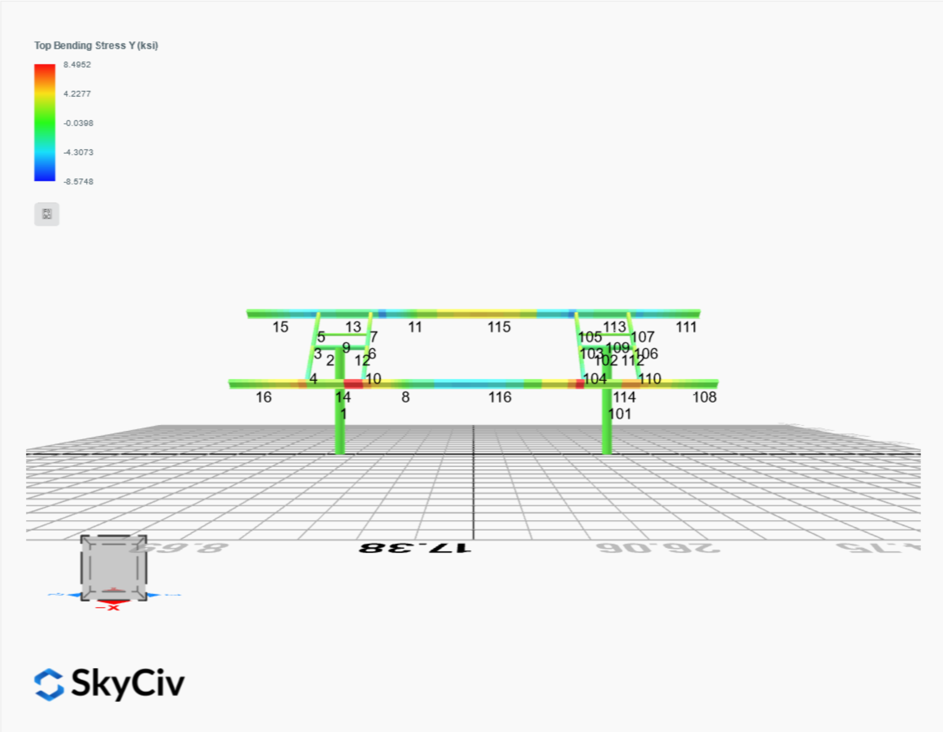

17.38
4.82
26.06
34.75
-3.86
-12.55
13.51
22.20
30.89
115
116
11
108
SkyCiv

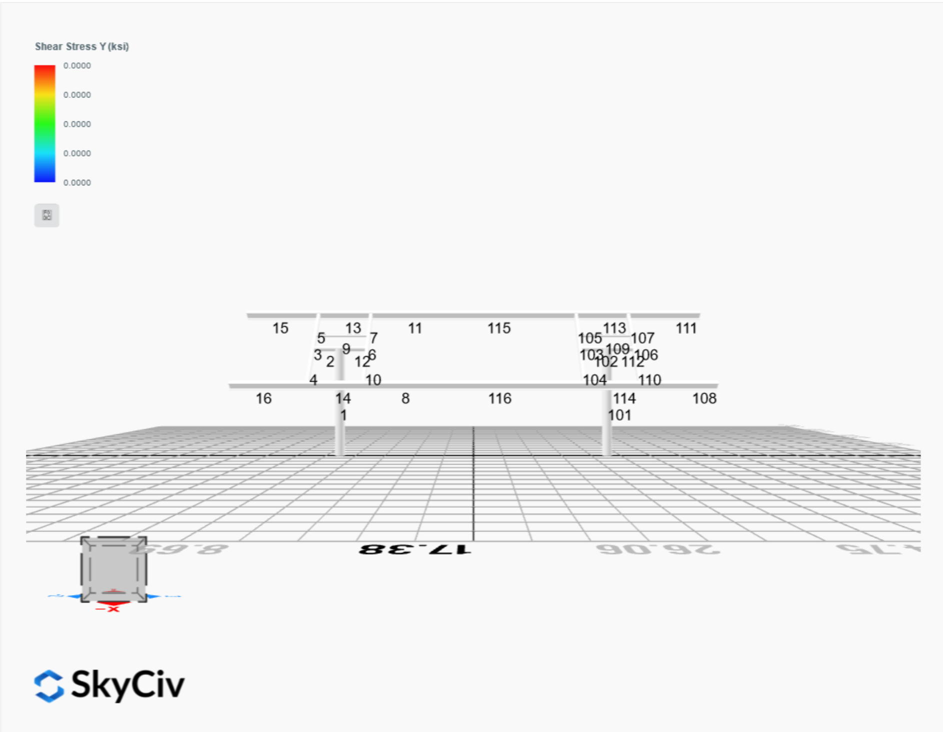

111
113
115
11
13
15
140
132
130
128
126
120
118
108
114
116
8
16
SkyCiv

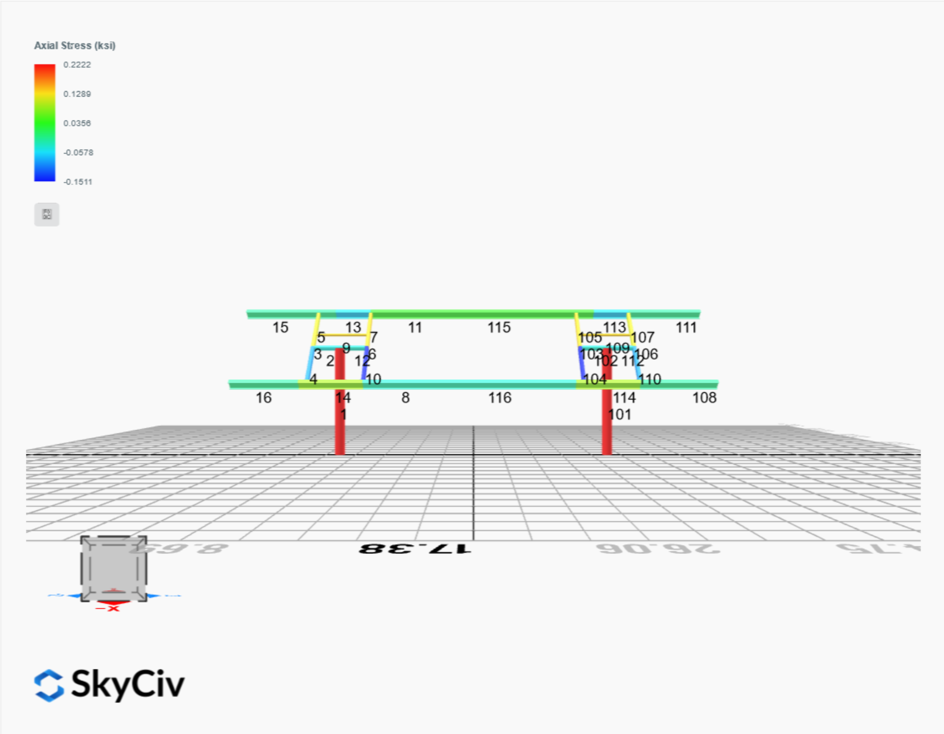
## FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
8.4952
4.2277
-0.0398
-4.3073
-8.5748
15
13
11
115
113
111
5
7
105
107
3
9
109
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
17.38
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
3
9
109
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
17.38
SkyCiv


Axial Stress (ksi)
0.2222
0.1289
0.0356
-0.0578
-0.1511
15
13
11
115
113
111
5
7
105
107
3
9
6
2
12
103
109
106
102
112
4
10
104
110
16
14
8
116
114
108
1
101
17.38
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 | 0.0000 | 1.9354 | 0.0373 | 0.0675 | -0.0158 | 0.0221 |
| ULS: 2. D + L | 0.0000 | 1.9354 | 0.0373 | 0.0675 | -0.0158 | 0.0221 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 3.8016 | 0.0840 | 0.1522 | -0.0362 | 0.0266 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 1.9354 | 0.0373 | 0.0675 | -0.0158 | 0.0221 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 3.3351 | 0.0724 | 0.1311 | -0.0311 | 0.0255 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 1.9354 | 0.0373 | 0.0675 | -0.0158 | 0.0221 |
| ULS: 5b. D + 0.7E | 0.0000 | 1.9354 | 0.0373 | 0.0675 | -0.0158 | 0.0221 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0000 | 3.3351 | 0.0724 | 0.1311 | -0.0311 | 0.0255 |
| ULS: 8. 0.6D + 0.7E | 0.0000 | 1.1613 | 0.0224 | 0.0405 | -0.0095 | 0.0133 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.7019 | 5.6373 | 0.1441 | 0.2250 | -0.4272 | 30.7350 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -3.7019 | 5.6373 | 0.1441 | 0.2250 | -0.4272 | 30.7350 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.6780 | -0.7425 | -0.0395 | -0.0457 | 0.2808 | -20.1300 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.3629 | -0.4275 | -0.0310 | -0.0332 | 0.2480 | -25.1308 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.7764 | 6.1115 | 0.1525 | 0.2492 | -0.3397 | 23.0602 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.7764 | 6.1115 | 0.1525 | 0.2492 | -0.3397 | 23.0602 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0085 | 1.3266 | 0.0148 | 0.0461 | 0.1914 | -15.0886 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.7722 | 1.5629 | 0.0211 | 0.0555 | 0.1667 | -18.8392 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.7764 | 4.7119 | 0.1174 | 0.1856 | -0.3244 | 23.0568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.7764 | 4.7119 | 0.1174 | 0.1856 | -0.3244 | 23.0568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0085 | -0.0730 | -0.0203 | -0.0174 | 0.2067 | -15.0920 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.7722 | 0.1632 | -0.0139 | -0.0081 | 0.1821 | -18.8426 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.7019 | 4.8632 | 0.1292 | 0.1980 | -0.4209 | 30.7262 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -3.7019 | 4.8632 | 0.1292 | 0.1980 | -0.4209 | 30.7262 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.6780 | -1.5167 | -0.0544 | -0.0727 | 0.2871 | -20.1389 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.3629 | -1.2017 | -0.0459 | -0.0602 | 0.2543 | -25.1396 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 9.4254 |
| Shear X | -6.1698 |
| Shear Z | 0.2464 |
| Moment X | 0.3863 |
| Moment Y (Twist) | 0.7140 |
| Moment Z | 51.5146 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 6.1115 |
| Shear X | -3.7019 |
| Shear Z | 0.1525 |
| Moment X | 0.2492 |
| Moment Y (Twist) | 0.4272 |
| Moment Z | 30.7350 |

## 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 | 1.9354 | -0.0373 | -0.0675 | 0.0158 | 0.0221 |
| ULS: 2. D + L | -0.0000 | 1.9354 | -0.0373 | -0.0675 | 0.0158 | 0.0221 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 3.8016 | -0.0840 | -0.1523 | 0.0362 | 0.0266 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 1.9354 | -0.0373 | -0.0675 | 0.0158 | 0.0221 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 3.3351 | -0.0724 | -0.1311 | 0.0311 | 0.0255 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 1.9354 | -0.0373 | -0.0675 | 0.0158 | 0.0221 |
| ULS: 5b. D + 0.7E | -0.0000 | 1.9354 | -0.0373 | -0.0675 | 0.0158 | 0.0221 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 3.3351 | -0.0724 | -0.1311 | 0.0311 | 0.0255 |
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.1613 | -0.0224 | -0.0405 | 0.0095 | 0.0133 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.7019 | 5.6373 | -0.1441 | -0.2250 | 0.4273 | 30.7350 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -3.7019 | 5.6373 | -0.1441 | -0.2250 | 0.4273 | 30.7350 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.6780 | -0.7425 | 0.0395 | 0.0457 | -0.2808 | -20.1300 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.3629 | -0.4275 | 0.0310 | 0.0332 | -0.2480 | -25.1308 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.7764 | 6.1115 | -0.1525 | -0.2492 | 0.3397 | 23.0602 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.7764 | 6.1115 | -0.1525 | -0.2492 | 0.3397 | 23.0602 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0085 | 1.3266 | -0.0148 | -0.0462 | -0.1913 | -15.0886 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.7722 | 1.5629 | -0.0211 | -0.0555 | -0.1667 | -18.8392 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.7764 | 4.7119 | -0.1174 | -0.1856 | 0.3244 | 23.0568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.7764 | 4.7119 | -0.1174 | -0.1856 | 0.3244 | 23.0568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0085 | -0.0730 | 0.0203 | 0.0174 | -0.2067 | -15.0920 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.7722 | 0.1632 | 0.0139 | 0.0081 | -0.1820 | -18.8426 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.7019 | 4.8632 | -0.1292 | -0.1980 | 0.4209 | 30.7262 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -3.7019 | 4.8632 | -0.1292 | -0.1980 | 0.4209 | 30.7262 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.6780 | -1.5167 | 0.0544 | 0.0727 | -0.2871 | -20.1389 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.3629 | -1.2017 | 0.0459 | 0.0602 | -0.2543 | -25.1396 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 9.4254 |
| Shear X | -6.1698 |
| Shear Z | -0.2464 |
| Moment X | -0.3863 |
| Moment Y (Twist) | 0.7142 |
| Moment Z | 51.5155 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 6.1115 |
| Shear X | -3.7019 |
| Shear Z | -0.1525 |
| Moment X | -0.2492 |
| Moment Y (Twist) | 0.4273 |
| Moment Z | 30.7350 |

## Project Details

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

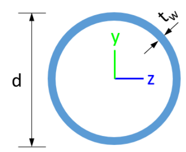
User Name: sales@mtsolar.us
Project Name: MTSOLAR_Steinhagen_PNS360_rev2
Unit System: imperial

## Design Input Information

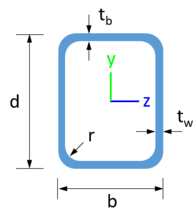
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

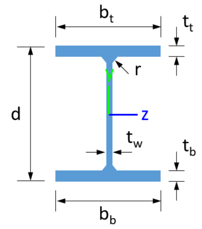
**Section Dimensions**




| 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 | | | | | |
| 9 | 8in Pipe Sch 40 | 8.63 | 0.32 | | | | | |




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




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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | 8in Pipe Sch 40 | 8.40 | 144.98 | 72.49 | 72.49 | 0.00 | 22.21 | 22.21 |
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 92.39 | 2.96 | 4.21 |
| 19 | W8x10 | 2.96 | 0.04 | 2.09 | 30.80 | 30.90 | 1.66 | 8.87 |

| **Member Properties** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 9 | 16.56 | 16.56 | 7.88 | - | 300 | 200 | 1 |
| 2 | 5 | 4.20 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,2.28,1.68,1.67,1.67,1.65,2.47,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.70,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.64,1.63,1.44,1.64,1.64,1.64,1.53,1.65,1.65,1.29,1.73,1.64,1.64,1.63,1.10,1.64,1.64,1.64,1.55 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.65,1.67,1.67,1.96,1.68,1.67,1.67,1.65,1.14,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 1.68,1.68,1.68,1.68,1.68,1.68,1.66,1.66,1.63,1.66,1.65,1.65,1.64,1.66,1.66,1.66,2.06,1.61,1.66,1.66,1.62,1.66,1.65,1.65,1.64,1.66 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.14,1.12,1.12,1.08,1.31,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.13 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.04,1.11,1.11,1.12,1.05,1.11,1.11,1.17,1.13,1.11,1.11,1.12,1.13,1.11,1.11,1.12,1.06 | 300 | 200 | 1 |
| 15 | 19 | 7.88 | 7.88 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 19 | 7.88 | 7.88 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 101 | 9 | 16.56 | 16.56 | 7.88 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.63,1.67,1.67,1.66,1.65,1.67,1.67,1.96,1.68,1.67,1.67,1.65,1.14,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.70,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.21,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 30 | 20 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | |
| 108 | 19 | 7.88 | 7.88 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,2.28,1.68,1.67,1.67,1.65,2.46,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 111 | 19 | 7.88 | 7.88 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 112 | 5 | 4.20 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.14,1.12,1.12,1.08,1.31,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.13 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.04,1.11,1.11,1.12,1.05,1.11,1.11,1.17,1.13,1.11,1.11,1.12,1.13,1.11,1.11,1.12,1.06 | 300 | 200 | 1 |
| 115 | 19 | 6.63 | 6.63 | 10.20 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.14,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12 | 300 | 200 | 1 |
| 116 | 19 | 6.63 | 6.63 | 10.20 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.10,1.12,1.12,1.12,1.11,1.12,1.12,2.83,1.13,1.12,1.12,1.12,1.04,1.12,1.12,1.12,1.11 | 300 | 200 | 1 |

## Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|---|---|---|---|---|---|---|
| 1 | 377.97 | 270.54 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 198.33 | 182.14 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 104.94 | 23.83 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 377.97 | 270.54 | 83.29 | 83.29 | 113.39 | 113.39 |
| 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 | 52.83 | 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 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 182.14 | 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 | 23.83 | 6.12 | 40.24 | 43.62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 115 | 133.20 | 69.16 | 17.33 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 69.16 | 16.09 | 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 | 0.035 | 0.619 | 0.019 | 0.054 | 0.002 | 0.641 | #13 | 0.338 | Not Required | Pass |
| 2 | 0.003 | 0.314 | 0.252 | 0.071 | 0.050 | 0.567 | #13 | 0.114 | Not Required | Pass |
| 3 | 0.007 | 0.636 | 0.033 | 0.063 | 0.003 | 0.652 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.006 | 0.569 | 0.106 | 0.057 | 0.023 | 0.625 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.007 | 0.395 | 0.100 | 0.063 | 0.025 | 0.406 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.009 | 0.709 | 0.066 | 0.072 | 0.013 | 0.755 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.009 | 0.440 | 0.141 | 0.071 | 0.036 | 0.464 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.001 | 0.087 | 0.120 | 0.044 | 0.014 | 0.125 | #21 | 0.095 | Not Required | Pass |
| 9 | 0.009 | 0.048 | 0.066 | 0.002 | 0.002 | 0.116 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.009 | 0.639 | 0.132 | 0.064 | 0.028 | 0.678 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.002 | 0.095 | 0.123 | 0.049 | 0.014 | 0.130 | #21 | 0.095 | Not Required | Pass |
| 12 | 0.002 | 0.385 | 0.284 | 0.083 | 0.054 | 0.670 | #13 | 0.053 | Not Required | Pass |
| 13 | 0.004 | 0.214 | 0.319 | 0.063 | 0.018 | 0.438 | #21 | 0.286 | Not Required | Pass |
| 14 | 0.005 | 0.197 | 0.314 | 0.057 | 0.018 | 0.424 | #21 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.069 | 0.112 | 0.030 | 0.008 | 0.161 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.062 | 0.112 | 0.027 | 0.008 | 0.158 | #21 | Not Required | Not Required | Pass |
| 101 | 0.035 | 0.619 | 0.019 | 0.054 | 0.002 | 0.641 | #13 | 0.338 | Not Required | Pass |
| 102 | 0.002 | 0.385 | 0.284 | 0.083 | 0.054 | 0.670 | #13 | 0.053 | Not Required | Pass |
| 103 | 0.009 | 0.709 | 0.066 | 0.072 | 0.013 | 0.755 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.009 | 0.639 | 0.132 | 0.064 | 0.028 | 0.678 | #13 | 0.080 | Not Required | Pass |
| 105 | 0.009 | 0.440 | 0.141 | 0.071 | 0.036 | 0.464 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.007 | 0.636 | 0.033 | 0.063 | 0.003 | 0.652 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.007 | 0.395 | 0.100 | 0.063 | 0.025 | 0.406 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.000 | 0.062 | 0.112 | 0.027 | 0.008 | 0.158 | #21 | Not Required | Not Required | Pass |
| 109 | 0.009 | 0.048 | 0.066 | 0.002 | 0.002 | 0.116 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.006 | 0.569 | 0.106 | 0.057 | 0.023 | 0.625 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.000 | 0.069 | 0.112 | 0.030 | 0.008 | 0.161 | #21 | Not Required | Not Required | Pass |
| 112 | 0.003 | 0.314 | 0.252 | 0.071 | 0.050 | 0.567 | #13 | 0.114 | Not Required | Pass |
| 113 | 0.004 | 0.214 | 0.319 | 0.063 | 0.018 | 0.438 | #21 | 0.190 | Not Required | Pass |
| 114 | 0.005 | 0.197 | 0.315 | 0.057 | 0.018 | 0.424 | #21 | 0.286 | Not Required | Pass |
| 115 | 0.004 | 0.334 | 0.177 | 0.049 | 0.014 | 0.435 | #13 | 0.473 | Not Required | Pass |
| 116 | 0.001 | 0.303 | 0.178 | 0.044 | 0.014 | 0.406 | #13 | 0.473 | 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 |
| LST | Limited slenderness for tension |
| LSC | Limited slenderness for compression |
| LD | Limited deflection |
| $P_n$ | Nominal axial strength (tension/comresssion) |
| $M_n$ | Nominal flexural strength (about Z/Y axis) |
| $V_n$ | Nominal shear strength (along Z/Y axis) |
| P | Design ratio in case of axial force |
| $M_z$ | Design ratio in case of bending about Z axis |
| $M_y$ | Design ratio in case of bending about Y axis |
| $V_y$ | Design ratio in case of shear along Y axis |
| $V_z$ | Design ratio in case of shear along Z axis |
| $(P,M_z,M_y)$ | Design ratio in case of axial force and bending action |
| KL/r | Design ratio in case of section slenderness |
| δ | Design ratio in case of member deflection |
| OK | Capacity is provided |
| NG | Capacity is not provided |

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

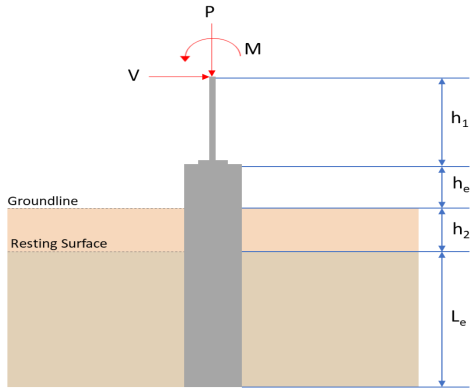
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.75\ \mathrm{ft}$ - 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) | 6.112 | 9.425 |
| $V_x$ (kip) | -3.702 | -6.170 |
| $V_z$ (kip) | 0.152 | 0.246 |
| $M_x$ (kipft) | 0.249 | 0.386 |
| $M_z$ (kipft) | 30.735 | 51.515 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-3.702\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.234\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(30.735 \text{ kipft}) + ((-3.702 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.245 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.4759 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.152 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.050667 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.249 \text{ kipft}) + ((0.152 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.083 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.8948 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.4759 \text{ ft}), (2.8948 \text{ ft})]$$

$$L_{e,req} = 7.476 \text{ ft}$$

$L_e$ - 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

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

$$Ratio = \frac{(7.476 \text{ ft})}{(8.75 \text{ ft})}$$

$$Ratio = 0.8544$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(6.112 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.86467\ \mathrm{kip/ft^2}$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.86467\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.43234$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.75\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -1.234\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 10.245\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.245\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-1.234\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (10.245\ \mathrm{kipft/ft})) + (4 \times (-1.234\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1342\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (10.245\ \mathrm{kipft/ft})) + (3 \times (-1.234\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (10.245\ \mathrm{kipft/ft})) + (2 \times (-1.234\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.12414\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (10.245\ \mathrm{kipft/ft})) + ((-1.234\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.1932\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1342\ \mathrm{ft})}{2}$$

$$p_a = 0.46007\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.12414\ \mathrm{kip/ft^2}\right)}{\left(0.46007\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.26983$$

Status: **PASS**
Ratio: **0.270**

$p_s$ - 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

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

$$Ratio = \frac{\left(1.1932\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90908$$

Status: **PASS**
Ratio: **0.910**

**Considering z-direction:**

$H_o = 0.050667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.083\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.083\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.083\ \mathrm{kipft/ft})) + (4 \times (0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.4026\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.083\ \mathrm{kipft/ft})) + (3 \times (0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.083\ \mathrm{kipft/ft})) + (2 \times (0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.037423\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.083\ \mathrm{kipft/ft})) + ((0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 0.07501\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.4026\ \mathrm{ft})}{2}$$

$$p_a = 0.4802\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.037423\ \mathrm{kip/ft^2}\right)}{\left(0.4802\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.077933$$

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

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

$$p_s = R\,L_e$$

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

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

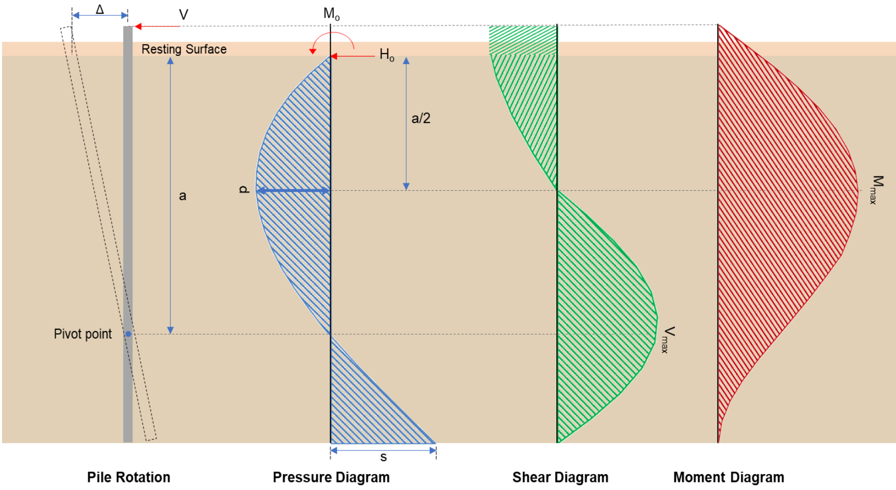
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.07501\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.057151$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-6.17\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -2.0567\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(51.515\ \mathrm{kipft}) + ((-6.17\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 17.172\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(17.172\ \mathrm{kipft/ft})}{(-2.0567\ \mathrm{kip/ft})}$$

$$E = 8.3493\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (17.172\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-2.0567\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (17.172\ \mathrm{kipft/ft})) + (4 \times (-2.0567\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1332\ \mathrm{ft}$$

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

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

$$V_{max} = ((-2.0567\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.3493\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1332\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.3493\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1332\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.495 \text{ kip}$$

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

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

$$M_{max} = ((-2.0567 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(8.3493 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.3493 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.3493 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 58.554 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.246 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.082 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.386 \text{ kipft}) + ((0.246 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.12867 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.12867 \text{ kipft/ft})}{(0.082 \text{ kip/ft})}$$

$$E = 1.5691 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.12867 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (0.082 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.12867 \text{ kipft/ft})) + (4 \times (0.082 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.4079 \text{ ft}$$

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

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

$$V_{max} = ((0.082 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.4079 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.4079 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.24444 \text{ kip}$$

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

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

$$M_{max} = ((0.082 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(1.5691 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.87955 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

*22.4.2.2, 10.6.1.1* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.425 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.079 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-37.079 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

| | | |
|---|---|---|
| | Main reinforcement: **6 - #5 (0.625 in)**<br>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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.425\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.0075165$$

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

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

**Parameters:**

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

*22.5.2.2* $d$ - Effective depth

$$d = 0.80\, D$$

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

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

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

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 9.425\ \mathrm{kip} \rightarrow 9425\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(9425\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 76.038\ \mathrm{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (76.038\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 76.038 \text{ kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.038 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.235 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 14.495 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.495 \text{ kip})}{(74.235 \text{ kip})}$$

$$Ratio = 0.19525$$

Status: **PASS**
Ratio: **0.200**

**Considering z-direction:**

$V_{max} = 0.24444 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.24444 \text{ kip})}{(74.235 \text{ kip})}$$

$$Ratio = 0.0032927$$

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

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

$S_m$ - Section modulus

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

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

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

| | | | |
|---|---|---|---|
| | $$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ | | |
| *14.5.2.1b* | $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:**<br>$M_{max} = 58.554\ \mathrm{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(58.554\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.94401$$ | | Status: **PASS**<br>Ratio: **0.940** |
| | **Considering z-direction:**<br>$M_{max} = 0.87955\ \mathrm{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.87955\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.01418$$ | | Status: **PASS**<br>Ratio: **0.010** |

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

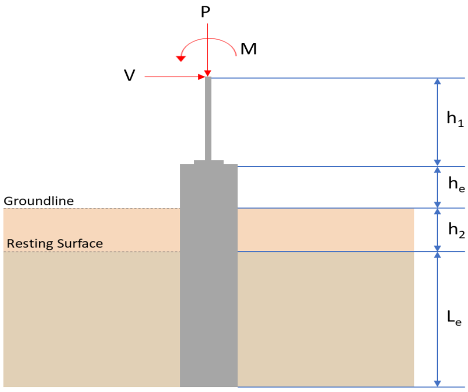
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round

$D = 36\ \mathrm{in}$ - Pile diameter

$L = 8.75\ \mathrm{ft}$ - 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) | 6.112 | 9.425 |
| $V_x$ (kip) | -3.702 | -6.170 |
| $V_z$ (kip) | -0.152 | -0.246 |
| $M_x$ (kipft) | -0.249 | -0.386 |
| $M_z$ (kipft) | 30.735 | 51.515 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-3.702\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.234\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(30.735\ \text{kipft}) + ((-3.702\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 10.245\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.4759\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.152\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.050667\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.249\ \text{kipft}) + ((-0.152\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.083\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.4905\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.4759\ \text{ft}), (1.4905\ \text{ft})]$$

$$L_{e,req} = 7.476\ \text{ft}$$

$L_e$ - 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

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

$$Ratio = \frac{(7.476\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.8544$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(6.112\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.86467 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.86467 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.43234$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -1.234 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 10.245 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.245 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-1.234 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (10.245 \text{ kipft/ft})) + (4 \times (-1.234 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.1342 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (10.245 \text{ kipft/ft})) + (3 \times (-1.234 \text{ kip/ft}) \times (8.75 \text{ ft}))]^{\,2}}{(8.75 \text{ ft})^2 \times [(3 \times (10.245 \text{ kipft/ft})) + (2 \times (-1.234 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.12414 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (10.245 \text{ kipft/ft})) + ((-1.234 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 1.1932 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.1342 \text{ ft})}{2}$$

$$p_a = 0.46007 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.12414 \text{ kip/ft}^2\right)}{\left(0.46007 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.26983$$

Status: **PASS**
Ratio: **0.270**

$p_s$ - 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

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

$$Ratio = \frac{\left(1.1932\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90908$$

Status: **PASS**
Ratio: **0.910**

**Considering z-direction:**

$H_o = -0.050667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.083\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.083\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.083\ \mathrm{kipft/ft})) + (4 \times (-0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.4026\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.083\ \mathrm{kipft/ft})) + (3 \times (-0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.083\ \mathrm{kipft/ft})) + (2 \times (-0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = -0.024032\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.083\ \mathrm{kipft/ft})) + ((-0.050667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = -0.03414\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.4026\ \mathrm{ft})}{2}$$

$$p_a = 0.4802\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.024032\ \mathrm{kip/ft^2}\right)}{\left(0.4802\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.050047$$

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

$p_s$ - 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

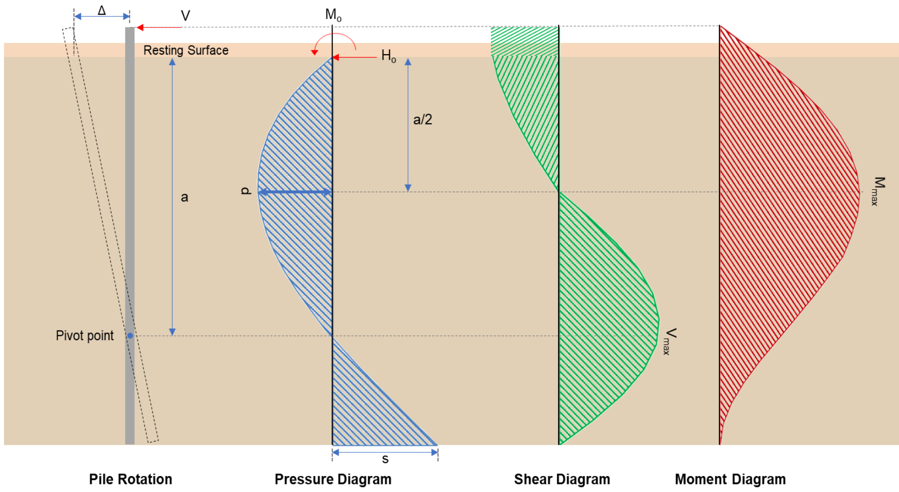
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.03414\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.026012$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-6.17\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -2.0567\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(51.515\ \mathrm{kipft}) + ((-6.17\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 17.172\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(17.172\ \mathrm{kipft/ft})}{(-2.0567\ \mathrm{kip/ft})}$$

$$E = 8.3493\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (17.172\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-2.0567\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (17.172\ \mathrm{kipft/ft})) + (4 \times (-2.0567\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1332\ \mathrm{ft}$$

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

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

$$V_{max} = ((-2.0567\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.3493\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1332\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (8.3493\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1332\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.495 \text{ kip}$$

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

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

$$M_{max} = ((-2.0567 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(8.3493 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (8.3493 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (8.3493 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.1332 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 58.554 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.246 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.082 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.386 \text{ kipft}) + ((-0.246 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.12867 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.12867 \text{ kipft/ft})}{(-0.082 \text{ kip/ft})}$$

$$E = 1.5691 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.12867 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-0.082 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.12867 \text{ kipft/ft})) + (4 \times (-0.082 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.4079 \text{ ft}$$

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

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

$$V_{max} = ((-0.082 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.4079 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.4079 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.24444 \text{ kip}$$

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

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

$$M_{max} = ((-0.082 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(1.5691 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.5691 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.4079 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.87955 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.425 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.079 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-37.079 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

| | | |
|---|---|---|
| 22.4.2.2 | **Axial Compression Strength (ACI 318-19, LRFD)**<br>$\phi P_N$ - Allowable axial compressive strength<br>$$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$<br>$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$<br>$$\phi P_N = 1253.9\ \mathrm{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(9.425\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$<br>$$Ratio = 0.0075165$$ | Status: **PASS**<br>Ratio: **0.010** |
| 22.5.2.2<br>22.5.5.1.3<br>22.5.5.1.1<br>22.5.5.1.1(a)<br>22.5.5.1.2 | **Shear Strength (ACI 318-19, LRFD)**<br>**Parameters:**<br>$b_w = 36\ \mathrm{in}$ - Effective width,<br>$d$ - Effective depth<br>$$d = 0.80\, D$$<br>$$d = 0.80 \times (36\ \mathrm{in})$$<br>$$d = 28.8\ \mathrm{in}$$<br>$\lambda_s$ - size effect modification factor<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$<br>$$\lambda_s = 0.71796$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,<br>$V_{c,max}$ - Max shear strength of concrete<br>$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$<br>$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$<br>$$V_{c,max} = 186.09\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 9.425\ \mathrm{kip} \rightarrow 9425\ \mathrm{lbf}$,<br>$V_{c,a}$ - 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>$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(9425\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$<br>$$V_{c,a} = 76.038\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,<br>$V_{c,b}$ - 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>$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$<br>$$V_{c,b} = 204.04\ \mathrm{kip}$$<br>$V_c$ - Governing shear strength of concrete<br>$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$<br>$$V_c = Min\left[(186.09\ \mathrm{kip}), (76.038\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$ | |

$$V_c = 76.038 \text{ kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.038 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.235 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 14.495 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.495 \text{ kip})}{(74.235 \text{ kip})}$$

$$Ratio = 0.19525$$

Status: **PASS**
Ratio: **0.200**

**Considering z-direction:**

$V_{max} = 0.24444 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.24444 \text{ kip})}{(74.235 \text{ kip})}$$

$$Ratio = 0.0032927$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

Therefore,
$\phi M_n$ - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 58.554 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(58.554 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.94401$$

Status: **PASS**
Ratio: **0.940**

**Considering z-direction:**

$M_{max} = 0.87955 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.87955 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.01418$$

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