# Your Project Calculations

Project Name: MTSOLAR_37BF297E65L19

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_37BF297E65L19&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=LadGIZ4kqwcCEWRLLVf0QpgS3gKCA2VTYG3a5AtlMFyJ6FnKHLIYxzsDbeQPYxj0

### Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 2P-19.75-8TOP-SD-57-L-4Hx5W-15GD |
| **Duty Classification:** | SD |
| **Module Width:** | 41.15 in |
| **Module Length:** | 87.25in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 5 |
| **Total Number of Modules:** | 20 |
| **Desired Tilt Angle:** | 60 |
| **Front Edge Clearance:** | 5 |
| **Total Array Height at Tilt:** | 16.95 ft |
| **Total Frame Length:** | 36.75 ft |
| **Frame Weight:** | 1596 lbs |
| **Array Dimensions N/S:** | 13.88 ft |
| **Array Dimensions E/W:** | 36.77 ft |
| **Rail Length:** | 166.60 in |
| **Rail Spacing:** | 3.64 ft |
| **Rail Check:** | Not Checked |

### Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 40 |
| **Pole Length above Grade:** | 11.01 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: 9.50 ft<br>Pile 2: 9.50 ft |
| **Foundation Volume:** | 4.974 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.299582 kip |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | Columbus, MT 59019, USA |
| **Wind Speed:** | 102 mph |
| **Snow Load:** | 41 psf |
| **Design Uplift Pressure:** | 0.022449 ksf |
| **Design Downforce Pressure:** | -0.022449 ksf |
| **Design Snow Pressure:** | 0.004509 ksf |

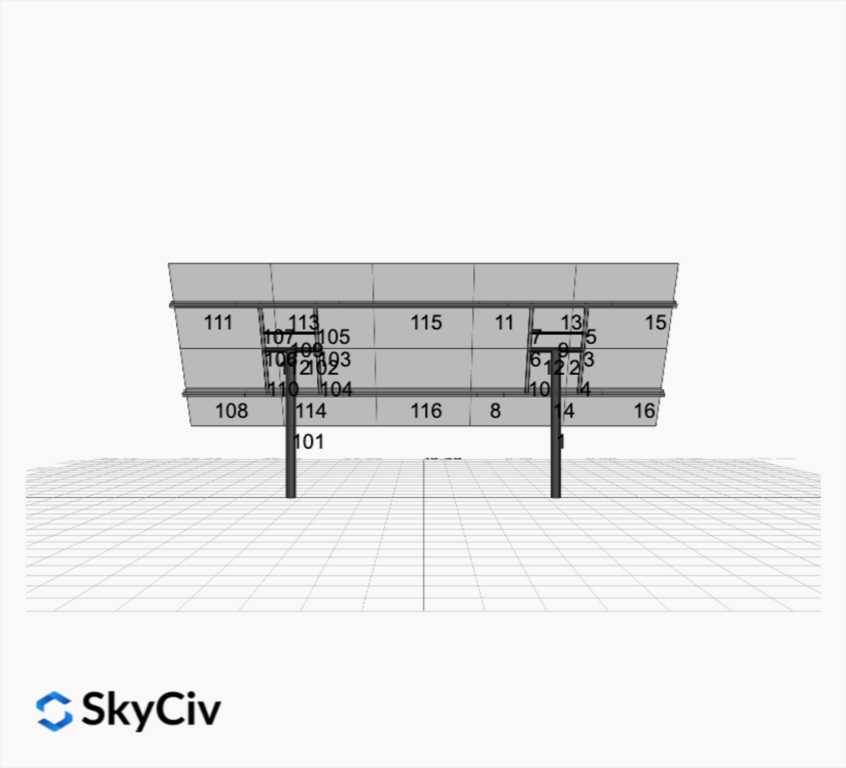

> ### Design Disclaimer
>
> This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

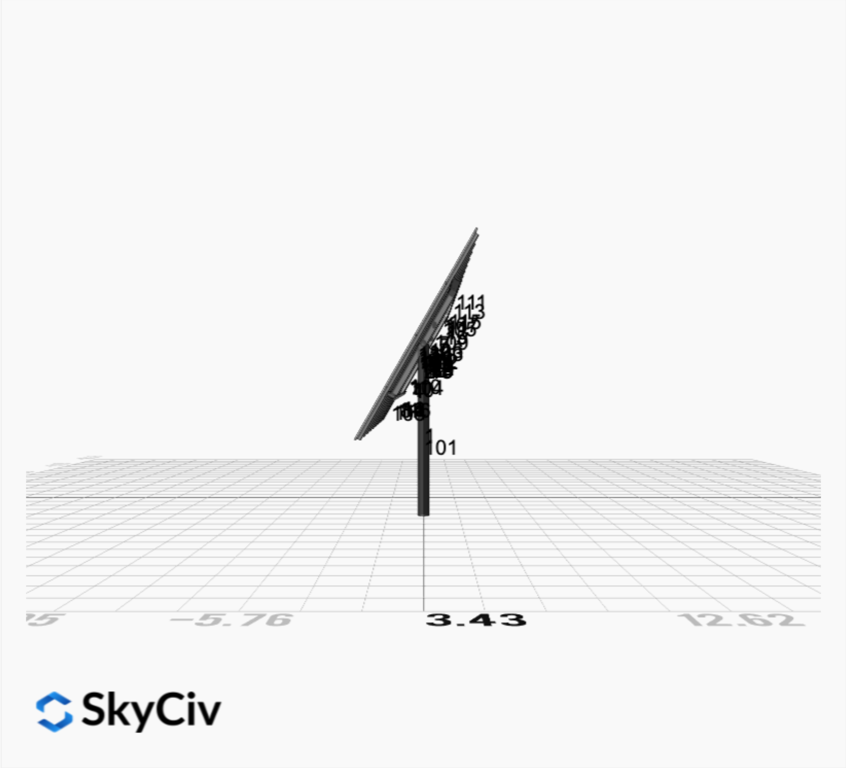
### AutoDesigner Input

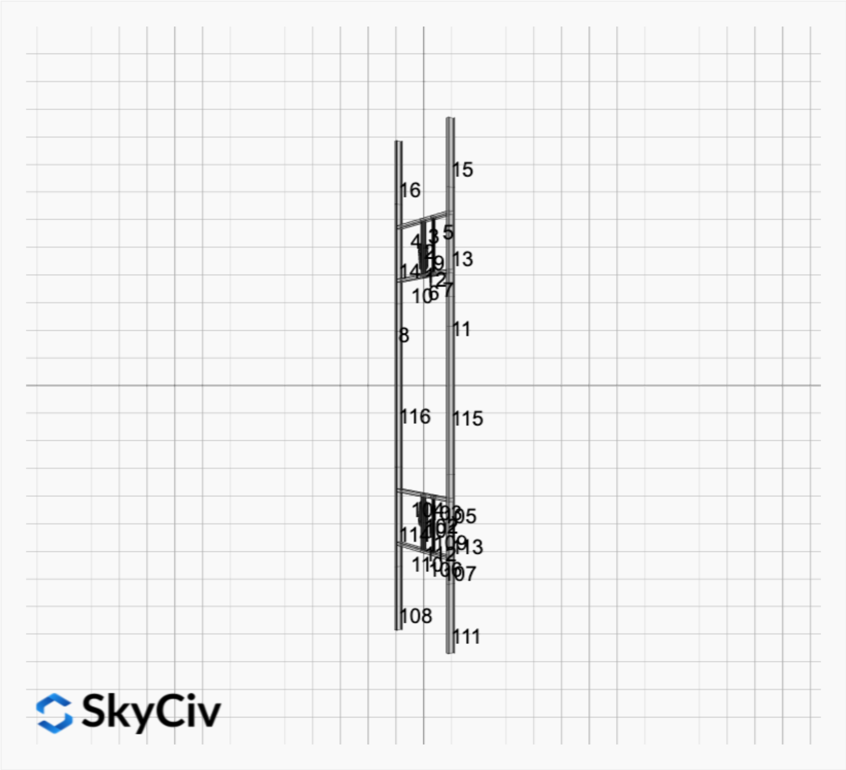

```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_37BF297E65L19","site_address":"Columbus, MT 59019, USA","module_width":41.15,"module_length":87.25,"number_rows":"4","number_columns":5,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":60,"ground_clearance":5,"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}
```

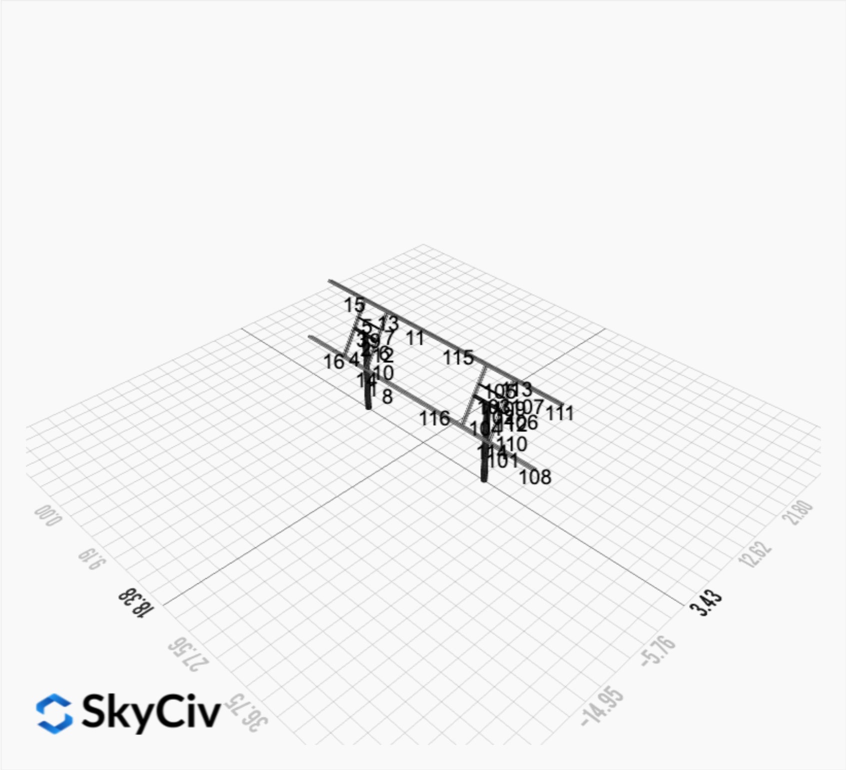

**Design Notes:**

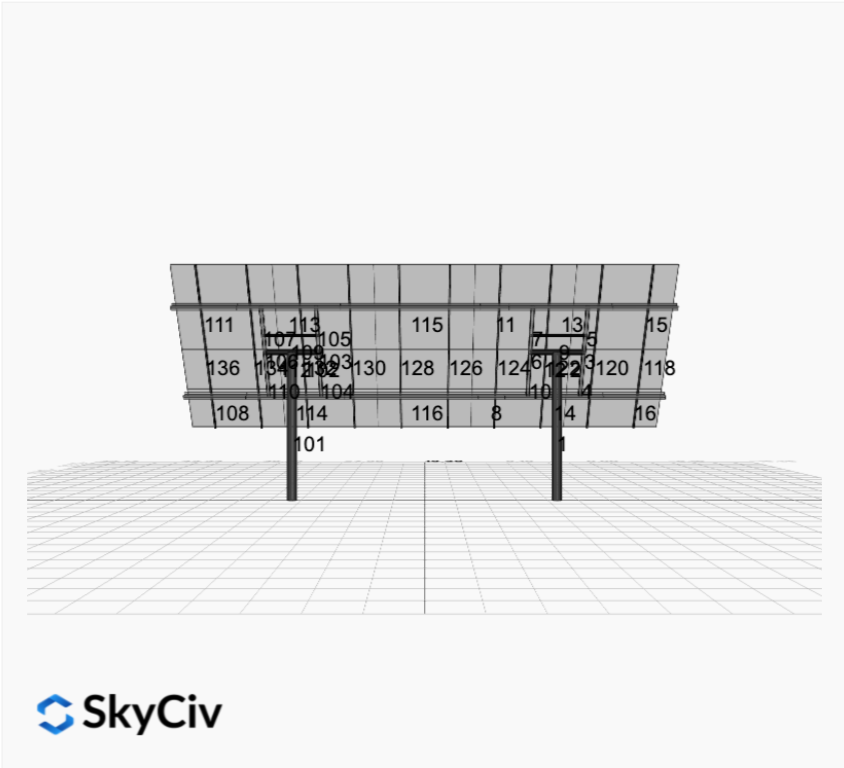
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



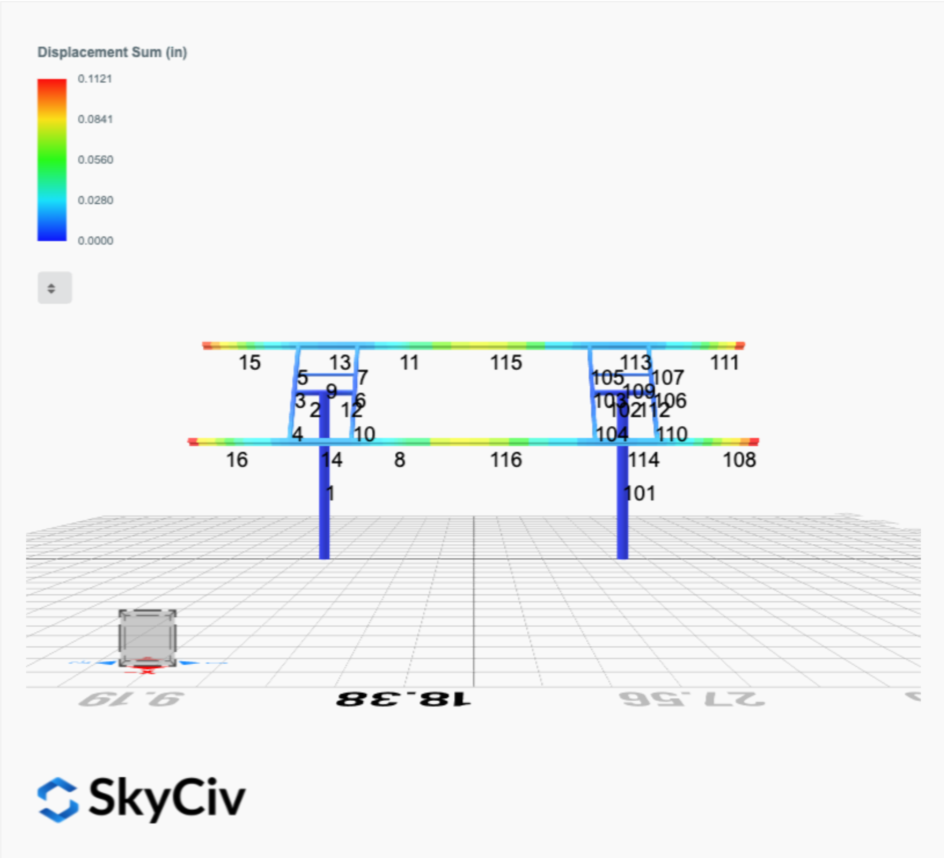


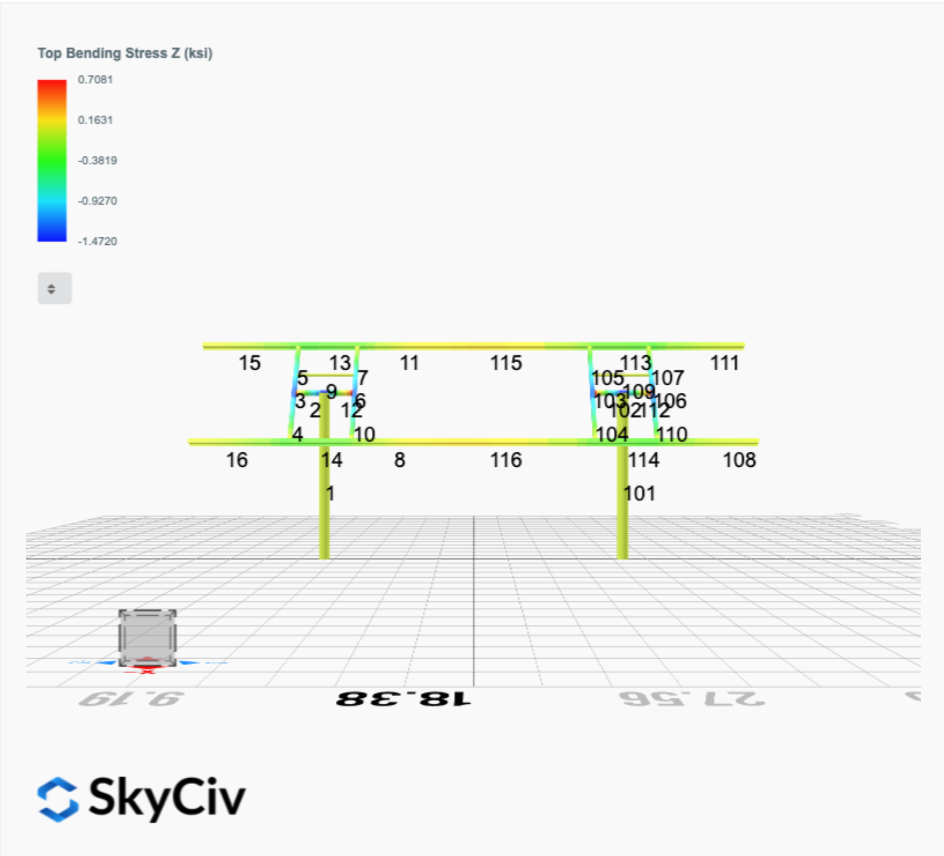


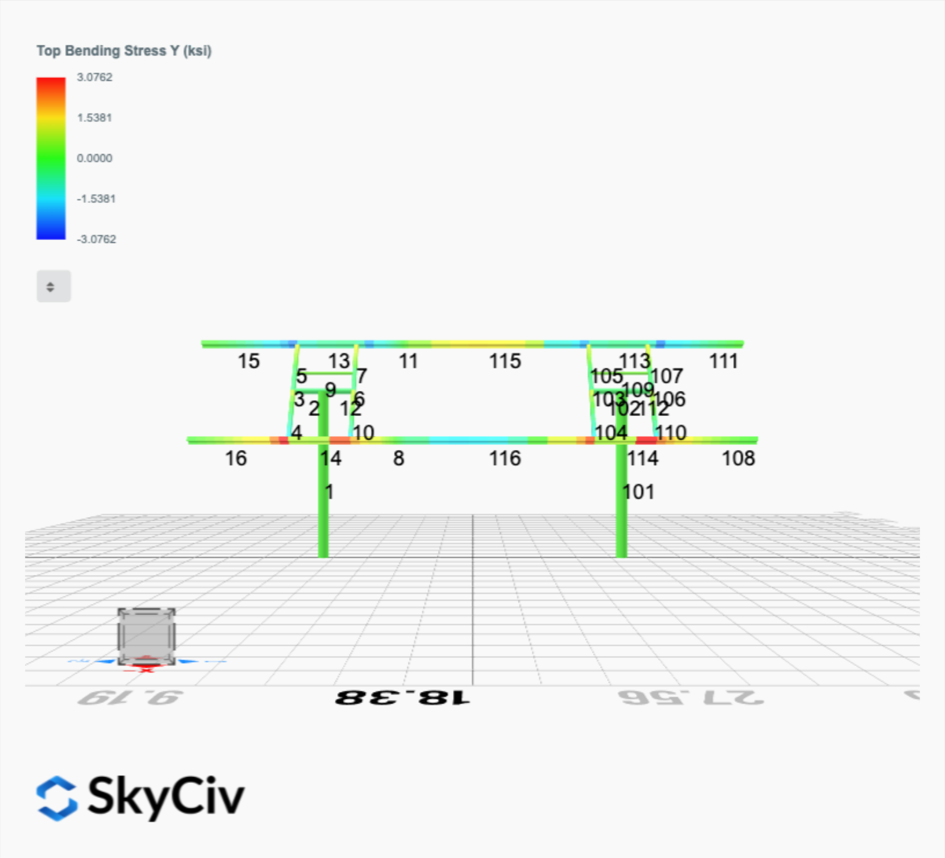


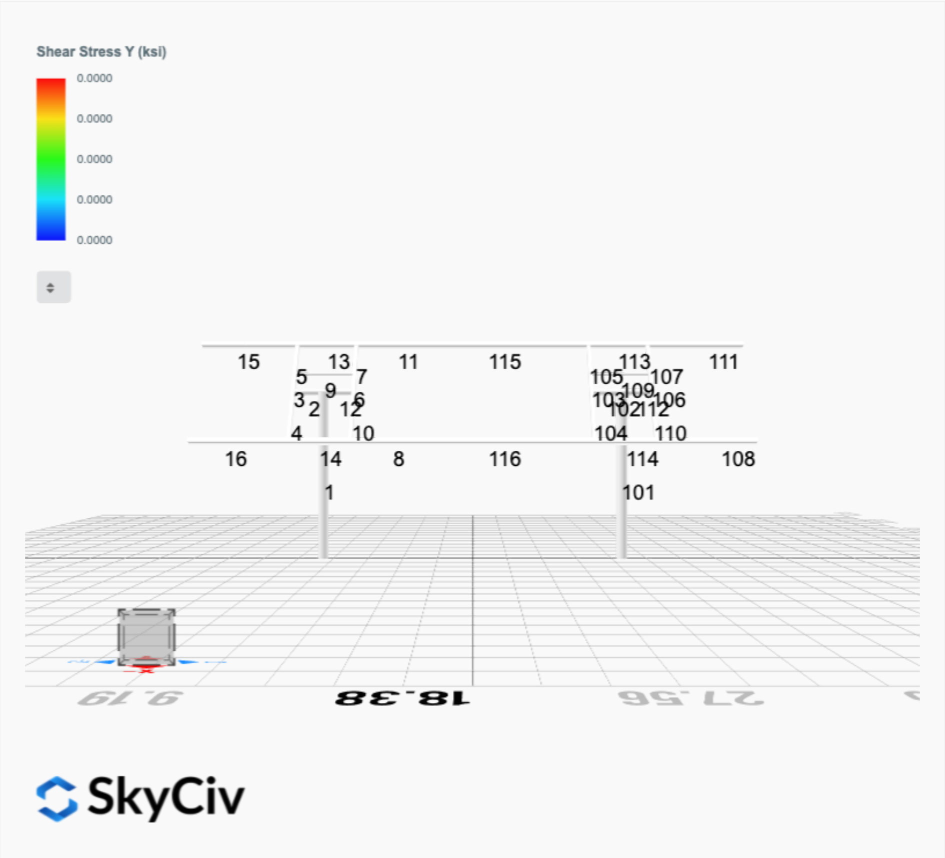

111
113
115
11
13
15
107
105
7
5
136
130
128
126
124
120
118
110
104
10
4
108
114
116
8
14
16
101
SkyCiv

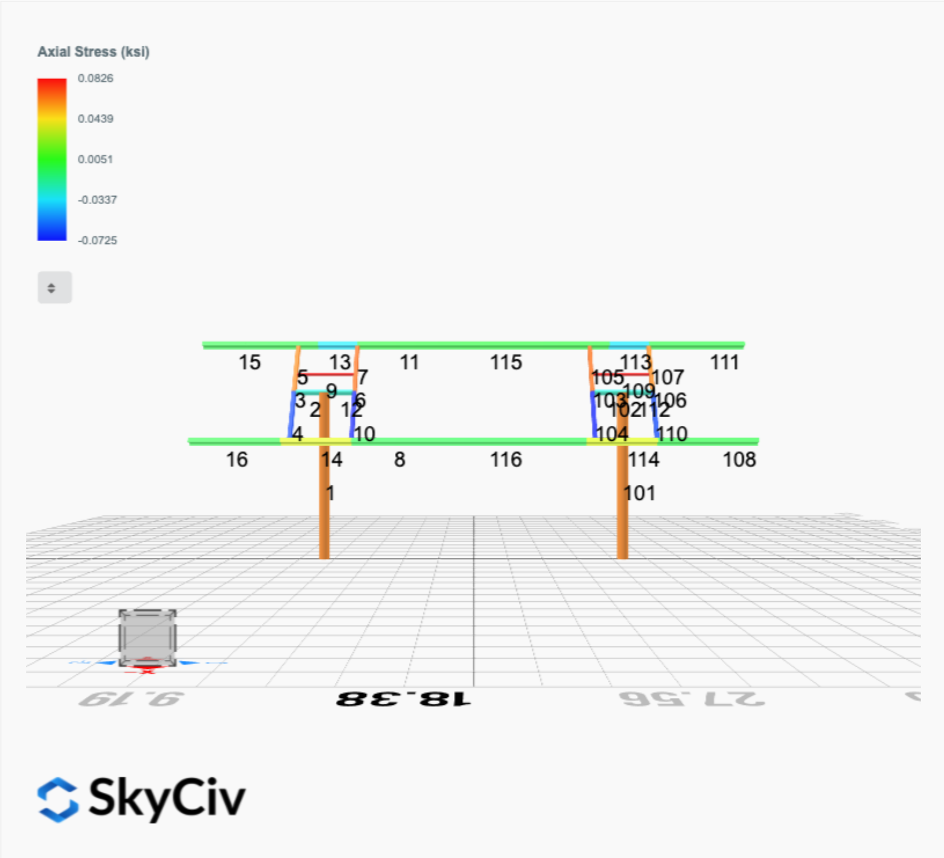
## FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
3.0762
1.5381
0.0000
-1.5381
-3.0762
15
13
11
115
113
111
16
14
8
116
114
108
1
101
9.19
18.38
27.56
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
13
11
115
113
111
16
14
8
116
114
108
1
101
9.19
18.38
27.56
SkyCiv



Axial Stress (ksi)
0.0826
0.0439
0.0051
-0.0337
-0.0725
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
9.19
18.38
27.56
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 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 2. D + L | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 2.5441 | 0.0023 | 0.0107 | 0.0682 | 0.0133 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 2.4003 | 0.0021 | 0.0099 | 0.0635 | 0.0132 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 5b. D + 0.7E | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0000 | 2.4003 | 0.0021 | 0.0099 | 0.0635 | 0.0132 |
| ULS: 8. 0.6D + 0.7E | 0.0000 | 1.1814 | 0.0010 | 0.0046 | 0.0297 | 0.0077 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.9775 | 3.6881 | -0.0164 | -0.0445 | 0.1877 | 33.0628 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.9775 | 0.2500 | 0.0195 | 0.0596 | -0.0887 | -32.5170 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2331 | 3.6896 | -0.0114 | -0.0292 | 0.1672 | 24.8007 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0000 | 2.4003 | 0.0021 | 0.0099 | 0.0635 | 0.0132 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.2331 | 1.1110 | 0.0155 | 0.0489 | -0.0401 | -24.3842 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0000 | 2.4003 | 0.0021 | 0.0099 | 0.0635 | 0.0132 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2331 | 3.2583 | -0.0119 | -0.0315 | 0.1532 | 24.8003 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.2331 | 0.6797 | 0.0151 | 0.0466 | -0.0542 | -24.3846 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0000 | 1.9690 | 0.0016 | 0.0077 | 0.0495 | 0.0128 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.9775 | 2.9005 | -0.0170 | -0.0476 | 0.1679 | 33.0577 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0000 | 1.1814 | 0.0010 | 0.0046 | 0.0297 | 0.0077 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.9775 | -0.5377 | 0.0189 | 0.0566 | -0.1085 | -32.5221 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0000 | 1.1814 | 0.0010 | 0.0046 | 0.0297 | 0.0077 |

### 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 | 5.5155 |
| Shear X | -4.9625 |
| Shear Z | 0.0322 |
| Moment X | 0.0976 |
| Moment Y (Twist) | 0.2995 |
| Moment Z | 55.5558 |

### 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 | 3.6896 |
| Shear X | -2.9775 |
| Shear Z | 0.0195 |
| Moment X | 0.0596 |
| Moment Y (Twist) | 0.1877 |
| Moment Z | 33.0628 |

## 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 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 2. D + L | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 2.5441 | -0.0023 | -0.0107 | -0.0682 | 0.0133 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 2.4003 | -0.0021 | -0.0099 | -0.0635 | 0.0132 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 5b. D + 0.7E | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 2.4003 | -0.0021 | -0.0099 | -0.0635 | 0.0132 |
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.1814 | -0.0010 | -0.0046 | -0.0297 | 0.0077 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.9775 | 3.6881 | 0.0164 | 0.0445 | -0.1877 | 33.0628 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.9775 | 0.2500 | -0.0195 | -0.0596 | 0.0888 | -32.5170 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2331 | 3.6896 | 0.0114 | 0.0292 | -0.1672 | 24.8007 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0000 | 2.4003 | -0.0021 | -0.0099 | -0.0635 | 0.0132 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.2331 | 1.1110 | -0.0155 | -0.0489 | 0.0401 | -24.3842 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0000 | 2.4003 | -0.0021 | -0.0099 | -0.0635 | 0.0132 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2331 | 3.2583 | 0.0119 | 0.0315 | -0.1532 | 24.8003 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.2331 | 0.6797 | -0.0151 | -0.0466 | 0.0542 | -24.3846 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0000 | 1.9690 | -0.0016 | -0.0077 | -0.0495 | 0.0128 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.9775 | 2.9005 | 0.0170 | 0.0476 | -0.1679 | 33.0577 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0000 | 1.1814 | -0.0010 | -0.0046 | -0.0297 | 0.0077 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.9775 | -0.5377 | -0.0189 | -0.0566 | 0.1085 | -32.5221 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0000 | 1.1814 | -0.0010 | -0.0046 | -0.0297 | 0.0077 |

### 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 | 5.5155 |
| Shear X | -4.9625 |
| Shear Z | -0.0322 |
| Moment X | -0.0976 |
| Moment Y (Twist) | 0.2996 |
| Moment Z | 55.5564 |

### 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 | 3.6896 |
| Shear X | -2.9775 |
| Shear Z | -0.0195 |
| Moment X | -0.0596 |
| Moment Y (Twist) | 0.1877 |
| Moment Z | 33.0628 |

## Project Details

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

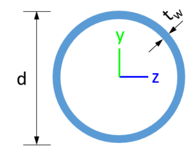
User Name: sales@mtsolar.us
Unit System: imperial

## Design Input Information

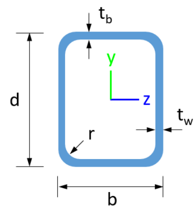
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

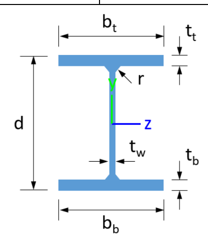
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2in Pipe Sch 40 | 2.38 | 0.15 | | | | | |
| 4 | 4in Pipe Sch 40 | 4.50 | 0.24 | | | | | |
| 9 | 8in Pipe Sch 40 | 8.63 | 0.32 | | | | | |




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




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

| Section Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | Name | A ($in^2$) | J ($in^4$) | $I_{yp}$ ($in^4$) | $I_{zp}$ ($in^4$) | $I_w$ ($in^6$) | $S_{yp}$ ($in^3$) | $S_{zp}$ ($in^3$) |
| 1 | 2in Pipe Sch 40 | 1.07 | 1.33 | 0.67 | 0.67 | 0.00 | 0.76 | 0.76 |
| 4 | 4in Pipe Sch 40 | 3.17 | 14.47 | 7.23 | 7.23 | 0.00 | 4.31 | 4.31 |
| 9 | 8in Pipe Sch 40 | 8.40 | 144.98 | 72.49 | 72.49 | 0.00 | 22.21 | 22.21 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | HSS5x3x1/8 | 1.77 | 6.02 | 2.75 | 6.03 | 152.35 | 2.07 | 2.93 |
| 18 | W6x9 | 2.68 | 0.04 | 2.20 | 16.40 | 17.70 | 1.72 | 6.23 |

**Member Properties**

| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 23.12 | 23.12 | 11.01 | - | 300 | 200 | 1 |
| 2 | 4 | 2.00 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 4 | 15 | 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 |
| 5 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 6 | 15 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 8 | 18 | 1.33 | 1.33 | 2.05 | 2.12,2.12,2.12,2.12,2.12,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12 | 300 | 200 | 1 |
| 9 | 1 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 15 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 11 | 18 | 1.33 | 1.33 | 2.05 | 2.12,2.12,2.12,2.12,2.12,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12,2.11,2.12 | 300 | 200 | 1 |
| 12 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 18 | 4.88 | 4.00 | 7.50 | 1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10 | 300 | 200 | 1 |
| 14 | 18 | 4.88 | 4.00 | 7.50 | 1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10 | 300 | 200 | 1 |
| 15 | 18 | 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 |
| 16 | 18 | 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 |
| 101 | 9 | 23.12 | 23.12 | 11.01 | - | 300 | 200 | 1 |
| 102 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 15 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 15 | 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 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 106 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 107 | 15 | 1.52 | 1.52 | 2.33 | 1.67,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 108 | 18 | 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 |
| 109 | 1 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 15 | 2.44 | 2.44 | 3.75 | 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 |
| 111 | 18 | 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 |
| 112 | 4 | 2.00 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 18 | 4.88 | 4.00 | 7.50 | 1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10 | 300 | 200 | 1 |
| 114 | 18 | 4.88 | 4.00 | 7.50 | 1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10 | 300 | 200 | 1 |
| 115 | 18 | 6.63 | 6.63 | 10.20 | 1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17 | 300 | 200 | 1 |
| 116 | 18 | 6.63 | 6.63 | 10.20 | 1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17 | 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 | 196.85 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 142.83 | 140.22 | 16.17 | 16.17 | 42.85 | 42.85 |
| 3 | 79.65 | 74.02 | 10.99 | 4.60 | 29.14 | 16.61 |
| 4 | 79.65 | 72.01 | 10.99 | 4.60 | 29.14 | 16.61 |
| 5 | 79.65 | 73.44 | 10.99 | 4.60 | 29.14 | 16.61 |
| 6 | 79.65 | 74.02 | 10.99 | 4.60 | 29.14 | 16.61 |
| 7 | 79.65 | 73.44 | 10.99 | 4.60 | 29.14 | 16.61 |
| 8 | 120.60 | 117.88 | 23.36 | 6.45 | 30.09 | 45.74 |
| 9 | 48.35 | 43.11 | 2.85 | 2.85 | 14.51 | 14.51 |
| 10 | 79.65 | 72.01 | 10.99 | 4.60 | 29.14 | 16.61 |
| 11 | 120.60 | 117.88 | 23.36 | 6.45 | 30.09 | 45.74 |
| 12 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 13 | 120.60 | 98.23 | 19.37 | 6.45 | 30.09 | 45.74 |
| 14 | 120.60 | 98.23 | 19.37 | 6.45 | 30.09 | 45.74 |
| 15 | 120.60 | 34.69 | 23.36 | 6.45 | 30.09 | 45.74 |
| 16 | 120.60 | 34.69 | 23.36 | 6.45 | 30.09 | 45.74 |
| 101 | 377.97 | 196.85 | 83.29 | 83.29 | 113.39 | 113.39 |
| 102 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 103 | 79.65 | 74.02 | 10.99 | 4.60 | 29.14 | 16.61 |
| 104 | 79.65 | 72.01 | 10.99 | 4.60 | 29.14 | 16.61 |
| 105 | 79.65 | 73.44 | 10.99 | 4.60 | 29.14 | 16.61 |
| 106 | 79.65 | 74.02 | 10.99 | 4.60 | 29.14 | 16.61 |
| 107 | 79.65 | 73.44 | 10.99 | 4.60 | 29.14 | 16.61 |
| 108 | 120.60 | 34.69 | 23.36 | 6.45 | 30.09 | 45.74 |
| 109 | 48.35 | 43.11 | 2.85 | 2.85 | 14.51 | 14.51 |
| 110 | 79.65 | 72.01 | 10.99 | 4.60 | 29.14 | 16.61 |
| 111 | 120.60 | 34.69 | 23.36 | 6.45 | 30.09 | 45.74 |
| 112 | 142.83 | 140.22 | 16.17 | 16.17 | 42.85 | 42.85 |
| 113 | 120.60 | 98.23 | 19.37 | 6.45 | 30.09 | 45.74 |
| 114 | 120.60 | 98.23 | 19.37 | 6.45 | 30.09 | 45.74 |
| 115 | 120.60 | 68.63 | 15.98 | 6.45 | 30.09 | 45.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 115 | 120.60 | 68.63 | 15.98 | 6.45 | 30.09 | 45.74 |
| 116 | 120.60 | 68.63 | 15.98 | 6.45 | 30.09 | 45.74 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.028 | 0.667 | 0.003 | 0.044 | 0.000 | 0.682 | #13 | 0.472 | Not Required | Pass |
| 2 | 0.002 | 0.265 | 0.309 | 0.061 | 0.059 | 0.574 | #13 | 0.053 | Not Required | Pass |
| 3 | 0.008 | 0.596 | 0.074 | 0.060 | 0.006 | 0.659 | #13 | 0.044 | Not Required | Pass |
| 4 | 0.008 | 0.594 | 0.202 | 0.060 | 0.025 | 0.691 | #13 | 0.078 | Not Required | Pass |
| 5 | 0.008 | 0.370 | 0.208 | 0.059 | 0.030 | 0.407 | #13 | 0.073 | Not Required | Pass |
| 6 | 0.009 | 0.575 | 0.082 | 0.057 | 0.007 | 0.641 | #13 | 0.044 | Not Required | Pass |
| 7 | 0.009 | 0.357 | 0.208 | 0.057 | 0.031 | 0.399 | #13 | 0.073 | Not Required | Pass |
| 8 | 0.000 | 0.042 | 0.072 | 0.038 | 0.009 | 0.098 | #21 | 0.088 | Not Required | Pass |
| 9 | 0.009 | 0.035 | 0.065 | 0.001 | 0.000 | 0.103 | #13 | 0.198 | Not Required | Pass |
| 10 | 0.008 | 0.572 | 0.202 | 0.058 | 0.025 | 0.688 | #13 | 0.078 | Not Required | Pass |
| 11 | 0.000 | 0.042 | 0.074 | 0.038 | 0.009 | 0.099 | #21 | 0.088 | Not Required | Pass |
| 12 | 0.002 | 0.251 | 0.290 | 0.059 | 0.057 | 0.542 | #13 | 0.034 | Not Required | Pass |
| 13 | 0.004 | 0.208 | 0.211 | 0.048 | 0.011 | 0.363 | #13 | 0.265 | Not Required | Pass |
| 14 | 0.004 | 0.211 | 0.211 | 0.048 | 0.011 | 0.363 | #13 | 0.177 | Not Required | Pass |
| 15 | 0.000 | 0.089 | 0.112 | 0.029 | 0.007 | 0.175 | #13 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.089 | 0.112 | 0.029 | 0.007 | 0.175 | #13 | Not Required | Not Required | Pass |
| 101 | 0.028 | 0.667 | 0.003 | 0.044 | 0.000 | 0.682 | #13 | 0.472 | Not Required | Pass |
| 102 | 0.002 | 0.251 | 0.290 | 0.059 | 0.057 | 0.542 | #13 | 0.034 | Not Required | Pass |
| 103 | 0.009 | 0.575 | 0.082 | 0.057 | 0.007 | 0.641 | #13 | 0.044 | Not Required | Pass |
| 104 | 0.008 | 0.572 | 0.202 | 0.058 | 0.025 | 0.688 | #13 | 0.078 | Not Required | Pass |
| 105 | 0.009 | 0.357 | 0.208 | 0.057 | 0.031 | 0.399 | #13 | 0.073 | Not Required | Pass |
| 106 | 0.008 | 0.596 | 0.074 | 0.060 | 0.006 | 0.659 | #13 | 0.044 | Not Required | Pass |
| 107 | 0.008 | 0.370 | 0.208 | 0.059 | 0.030 | 0.407 | #13 | 0.073 | Not Required | Pass |
| 108 | 0.000 | 0.089 | 0.112 | 0.029 | 0.007 | 0.175 | #13 | Not Required | Not Required | Pass |
| 109 | 0.009 | 0.035 | 0.065 | 0.001 | 0.000 | 0.103 | #13 | 0.198 | Not Required | Pass |
| 110 | 0.008 | 0.594 | 0.202 | 0.060 | 0.025 | 0.691 | #13 | 0.078 | Not Required | Pass |
| 111 | 0.000 | 0.089 | 0.112 | 0.029 | 0.007 | 0.175 | #13 | Not Required | Not Required | Pass |
| 112 | 0.002 | 0.265 | 0.309 | 0.061 | 0.059 | 0.574 | #13 | 0.053 | Not Required | Pass |
| 113 | 0.004 | 0.208 | 0.211 | 0.048 | 0.011 | 0.363 | #13 | 0.177 | Not Required | Pass |
| 114 | 0.004 | 0.211 | 0.211 | 0.048 | 0.011 | 0.363 | #13 | 0.265 | Not Required | Pass |
| 115 | 0.000 | 0.157 | 0.113 | 0.038 | 0.009 | 0.244 | #13 | 0.439 | Not Required | Pass |
| 116 | 0.000 | 0.157 | 0.114 | 0.038 | 0.009 | 0.245 | #13 | 0.439 | 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 |
|---|---|---|

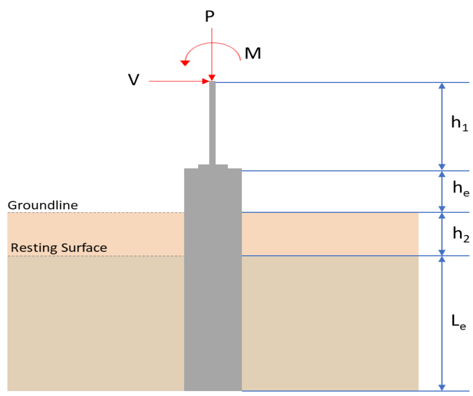
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 9.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 3.690 | 5.516 |
| $V_x$ (kip) | -2.978 | -4.963 |
| $V_z$ (kip) | 0.020 | 0.032 |
| $M_x$ (kipft) | 0.060 | 0.098 |
| $M_z$ (kipft) | 33.063 | 55.556 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.978\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.99267\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(33.063\ \text{kipft}) + ((-2.978\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.021\ \text{kipft/ft}$$

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:
$L_{e,x} = 8.4204\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.02\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.0066667\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.06\ \text{kipft}) + ((0.02\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

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

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:
$L_{e,z} = 1.5132\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.4204\ \text{ft}), (1.5132\ \text{ft})]$$

$$L_{e,req} = 8.42\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.42\ \text{ft})}{(9.5\ \text{ft})}$$

$$Ratio = 0.88632$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(3.69\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.52203\ \mathrm{kip/ft^2}$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.52203\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.26101$$

Status: **PASS**
Ratio: **0.260**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 3.1667$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.99267\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.021\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.021\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (-0.99267\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (11.021\ \mathrm{kipft/ft})) + (4 \times (-0.99267\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.6209\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.021\ \mathrm{kipft/ft})) + (3 \times (-0.99267\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]^{\ 2}}{(9.5\ \mathrm{ft})^2 \times [(3 \times (11.021\ \mathrm{kipft/ft})) + (2 \times (-0.99267\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}$$

$$p = 0.22923\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (11.021\ \mathrm{kipft/ft})) + ((-0.99267\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}{(9.5\ \mathrm{ft})^2}$$

$$s = 1.3171\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.6209\ \mathrm{ft})}{2}$$

$$p_a = 0.49657\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22923\ \mathrm{kip/ft^2}\right)}{\left(0.49657\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.46163$$

Status: **PASS**
Ratio: **0.460**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$

$$p_s = 1.425\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3171\ \mathrm{kip/ft^2}\right)}{\left(1.425\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92425$$

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

**Considering z-direction:**

$H_o = 0.0066667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.02\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.02\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.02\ \mathrm{kipft/ft})) + (4 \times (0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.8705\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.02\ \mathrm{kipft/ft})) + (3 \times (0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]^{\ 2}}{(9.5\ \mathrm{ft})^2 \times [(3 \times (0.02\ \mathrm{kipft/ft})) + (2 \times (0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}$$

$$p = 0.0050975\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.02\ \mathrm{kipft/ft})) + ((0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}{(9.5\ \mathrm{ft})^2}$$

$$s = 0.010791\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.8705\ \mathrm{ft})}{2}$$

$$p_a = 0.51529\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0050975\ \mathrm{kip/ft^2}\right)}{\left(0.51529\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0098925$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$

$$p_s = 1.425\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

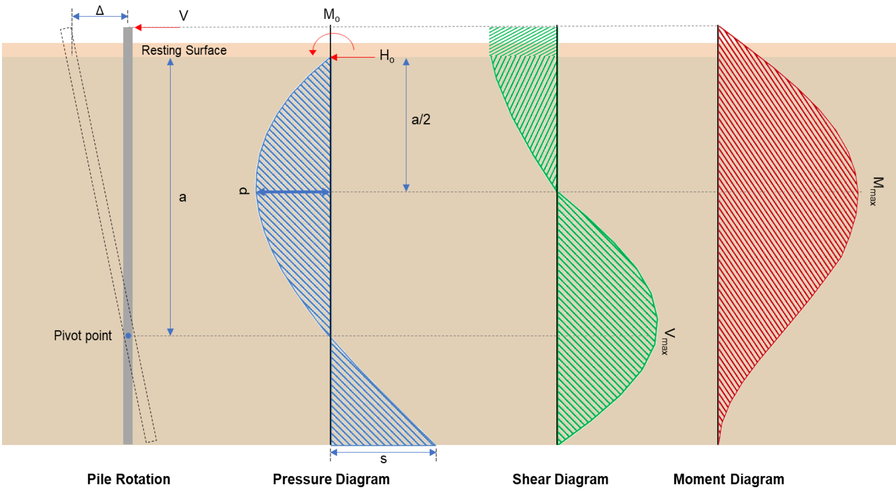
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.010791 \text{ kip/ft}^2\right)}{\left(1.425 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0075729$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.963 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.6543 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(55.556 \text{ kipft}) + ((-4.963 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 18.519 \text{ kipft/ft}$$

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

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

$$E = \frac{(18.519 \text{ kipft/ft})}{(-1.6543 \text{ kip/ft})}$$

$$E = 11.194 \text{ ft}$$

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

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

$$a = \frac{(4 \times (18.519 \text{ kipft/ft}) \times (9.5 \text{ ft})) + \left(3 \times (-1.6543 \text{ kip/ft}) \times (9.5 \text{ ft})^2\right)}{(6 \times (18.519 \text{ kipft/ft})) + (4 \times (-1.6543 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.6194 \text{ ft}$$

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

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

$$V_{max} = ((-1.6543 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.6194 \text{ ft})}{(9.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.6194 \text{ ft})}{(9.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 13.622 \text{ kip}$$

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

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

$$M_{max} = ((-1.6543 \text{ kip/ft}) \times (36 \text{ in}) \times (9.5 \text{ ft})) \times \left[\left(\frac{(11.194 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 60.449 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.032 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.010667 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.098 \text{ kipft}) + ((0.032 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.032667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.032667 \text{ kipft/ft})}{(0.010667 \text{ kip/ft})}$$

$$E = 3.0625 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.032667 \text{ kipft/ft}) \times (9.5 \text{ ft})) + \left(3 \times (0.010667 \text{ kip/ft}) \times (9.5 \text{ ft})^2\right)}{(6 \times (0.032667 \text{ kipft/ft})) + (4 \times (0.010667 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.867 \text{ ft}$$

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

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

$$V_{max} = ((0.010667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.867 \text{ ft})}{(9.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.867 \text{ ft})}{(9.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.039719 \text{ kip}$$

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

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

$$M_{max} = ((0.010667 \text{ kip/ft}) \times (36 \text{ in}) \times (9.5 \text{ ft})) \times \left[\left(\frac{(3.0625 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.1617 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(5.516 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -37.201 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-37.201 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

| | | | |
|---|---|---|---|
| 22.4.2.2 | **Axial Compression Strength (ACI 318-19, LRFD)**<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>$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$<br>$$\phi P_N = 1253.9\ \text{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(5.516\ \text{kip})}{(1253.9\ \text{kip})}$$<br>$$Ratio = 0.004399$$ | Status: **PASS**<br>Ratio: **0.000** | |

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 5.516\ \text{kip} \rightarrow 5516\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(5516\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.374\ \text{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.374\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.374 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((75.374 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 73.804 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 13.622 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.622 \text{ kip})}{(73.804 \text{ kip})}$$

$$Ratio = 0.18458$$

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

**Considering z-direction:**

$V_{max} = 0.039719 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.039719 \text{ kip})}{(73.804 \text{ kip})}$$

$$Ratio = 0.00053817$$

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

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

$S_m$ - Section modulus

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

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

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

| | | | |
|---|---|---|---|
| | $S_m = 4580.4\ \mathrm{in}^3$<br>$\lambda = 1$ - 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>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$<br>$$\phi M_{n,1} = 62.027kipft$$ | | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$<br>$$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$<br>$$\phi M_n = 62.027\ \mathrm{kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 60.449\ \mathrm{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(60.449\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$<br>$$Ratio = 0.97455$$ | | Status: **PASS**<br>Ratio: **0.970** |
| | **Considering z-direction:**<br>$M_{max} = 0.1617\ \mathrm{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.1617\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$<br>$$Ratio = 0.0026069$$ | | Status: **PASS**<br>Ratio: **0.000** |

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

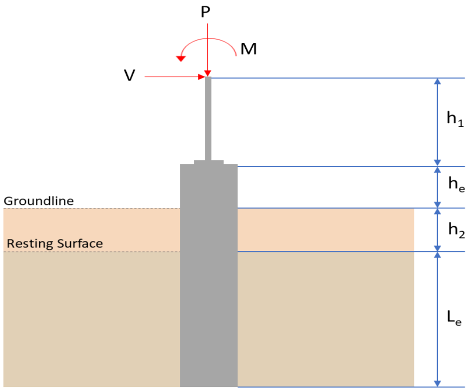
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round

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

$L = 9.5\ \mathrm{ft}$ - Total pile length

$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface

$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 3.690 | 5.516 |
| $V_x$ (kip) | -2.978 | -4.963 |
| $V_z$ (kip) | -0.020 | -0.032 |
| $M_x$ (kipft) | -0.060 | -0.098 |
| $M_z$ (kipft) | 33.063 | 55.556 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.978\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.99267\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(33.063 \text{ kipft}) + ((-2.978 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 11.021 \text{ kipft/ft}$$

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:
$L_{e,x} = 8.4204 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.02 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0066667 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.06 \text{ kipft}) + ((-0.02 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

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

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:
$L_{e,z} = 1.2062 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.4204 \text{ ft}), (1.2062 \text{ ft})]$$

$$L_{e,req} = 8.42 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.42 \text{ ft})}{(9.5 \text{ ft})}$$

$$Ratio = 0.88632$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(3.69 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.52203 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.52203 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.26101$$

Status: **PASS**
Ratio: **0.260**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 3.1667$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.99267 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 11.021 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.021 \text{ kipft/ft}) \times (9.5 \text{ ft})) + \left(3 \times (-0.99267 \text{ kip/ft}) \times (9.5 \text{ ft})^2\right)}{(6 \times (11.021 \text{ kipft/ft})) + (4 \times (-0.99267 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.6209 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.021 \text{ kipft/ft})) + (3 \times (-0.99267 \text{ kip/ft}) \times (9.5 \text{ ft}))]^2}{(9.5 \text{ ft})^2 \times [(3 \times (11.021 \text{ kipft/ft})) + (2 \times (-0.99267 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = 0.22923 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (11.021 \text{ kipft/ft})) + ((-0.99267 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = 1.3171 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.6209 \text{ ft})}{2}$$

$$p_a = 0.49657 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.22923 \text{ kip/ft}^2)}{(0.49657 \text{ kip/ft}^2)}$$

$$Ratio = 0.46163$$

Status: **PASS**
Ratio: **0.460**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$

$$p_s = 1.425\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3171\ \mathrm{kip/ft^2}\right)}{\left(1.425\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92425$$

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

**Considering z-direction:**

$H_o = -0.0066667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.02\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.02\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (-0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.02\ \mathrm{kipft/ft})) + (4 \times (-0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.8705\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times \left[(4 \times (0.02\ \mathrm{kipft/ft})) + (3 \times (-0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))\right]^2}{(9.5\ \mathrm{ft})^2 \times \left[(3 \times (0.02\ \mathrm{kipft/ft})) + (2 \times (-0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))\right]}$$

$$p = -0.0023691\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times \left[(2 \times (0.02\ \mathrm{kipft/ft})) + ((-0.0066667\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))\right]}{(9.5\ \mathrm{ft})^2}$$

$$s = -0.0024367\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.8705\ \mathrm{ft})}{2}$$

$$p_a = 0.51529\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0023691\ \mathrm{kip/ft^2}\right)}{\left(0.51529\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0045975$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$

$$p_s = 1.425\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

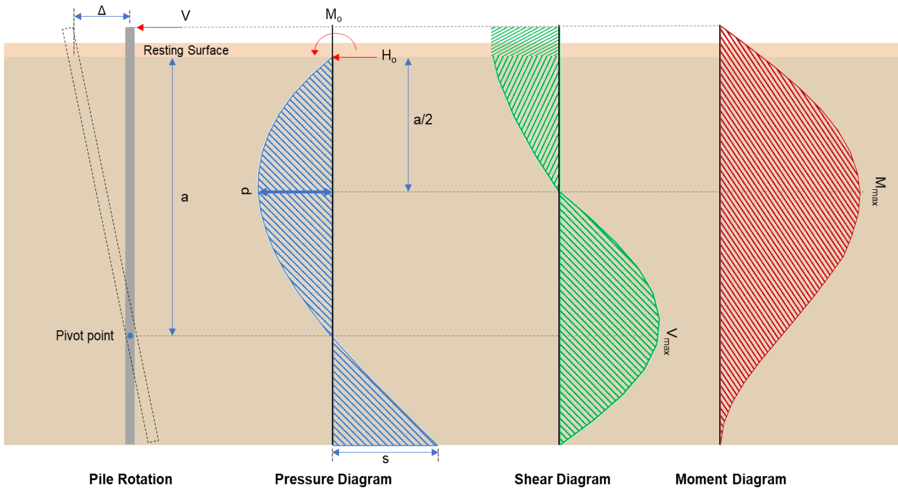
$$Ratio = \frac{s}{\phantom{p}}$$

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

$$Ratio = \frac{\left(-0.0024367\ \mathrm{kip/ft^2}\right)}{\left(1.425\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00171$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.963\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.6543\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(55.556\ \mathrm{kipft}) + ((-4.963\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 18.519\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(18.519\ \mathrm{kipft/ft})}{(-1.6543\ \mathrm{kip/ft})}$$

$$E = 11.194\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (18.519\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (-1.6543\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (18.519\ \mathrm{kipft/ft})) + (4 \times (-1.6543\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.6194\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.6543\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.194\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.6194\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.194\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.6194\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.622 \text{ kip}$$

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

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

$$M_{max} = ((-1.6543 \text{ kip/ft}) \times (36 \text{ in}) \times (9.5 \text{ ft})) \times \left[\left(\frac{(11.194 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.194 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.6194 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 60.449 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.032 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.010667 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.098 \text{ kipft}) + ((-0.032 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.032667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.032667 \text{ kipft/ft})}{(-0.010667 \text{ kip/ft})}$$

$$E = 3.0625 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.032667 \text{ kipft/ft}) \times (9.5 \text{ ft})) + \left(3 \times (-0.010667 \text{ kip/ft}) \times (9.5 \text{ ft})^2\right)}{(6 \times (0.032667 \text{ kipft/ft})) + (4 \times (-0.010667 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.867 \text{ ft}$$

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

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

$$V_{max} = ((-0.010667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.867 \text{ ft})}{(9.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.867 \text{ ft})}{(9.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.039719 \text{ kip}$$

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

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

$$M_{max} = ((-0.010667 \text{ kip/ft}) \times (36 \text{ in}) \times (9.5 \text{ ft})) \times \left[\left(\frac{(3.0625 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0625 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.867 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.1617 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(5.516 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -37.201 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-37.201 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

### Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 $\phi P_N$ - 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

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

$$Ratio = \frac{(5.516\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.004399$$

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

### 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 $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 5.516\ \mathrm{kip} \rightarrow 5516\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(5516\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 75.374\ \mathrm{kip}$$

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

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (75.374\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 75.374 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((75.374 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 73.804 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 13.622 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.622 \text{ kip})}{(73.804 \text{ kip})}$$

$$Ratio = 0.18458$$

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

**Considering z-direction:**

$V_{max} = 0.039719 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.039719 \text{ kip})}{(73.804 \text{ kip})}$$

$$Ratio = 0.00053817$$

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:**

$M_{max} = 60.449 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(60.449 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.97455$$

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

**Considering z-direction:**

$M_{max} = 0.1617 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.1617 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0026069$$

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