# Project Details

**Project Name:** VA Tech - V1Jb

**Location:** Smithfield Rd, Blacksburg, VA 24061, USA

**Unique ID:** 2P-17-6TOP-HD-24-L-4Hx5W-780I

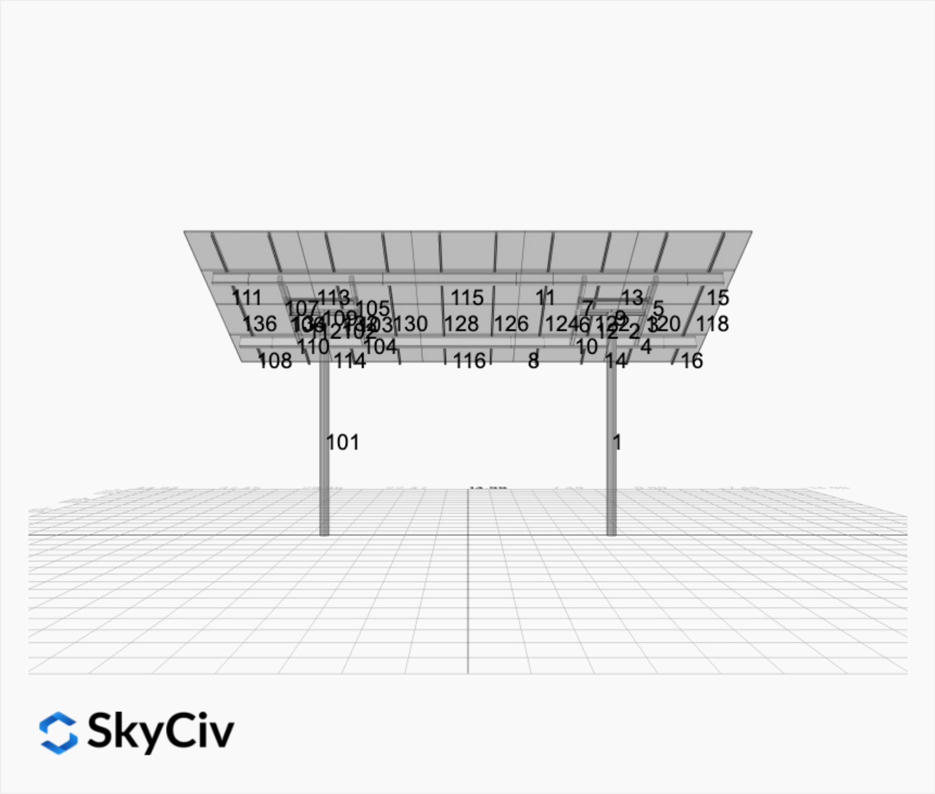
**Dealer:** ______________________________

**Date:** Tue May 27 2025

**Number of Modules:** 20

**Number of Poles:** 2

**Date Sold:** ______________________________



| Array Dimensions N/S | 15.03 ft |
|---|---|
| **Array Dimensions E/W** | 29.96 ft |
| **Winter Tilt Angle** | 25 |
| **Front Edge Clearance** | 10 ft |

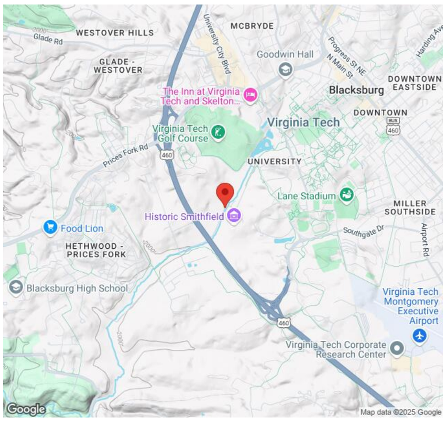
### MT Solar Bill of Materials (2P-17-6TOP-HD-24-L-4Hx5W-780I)

| Part | Short Description | BOM Qty |
|---|---|---|
| MTS-PC-6 | 6IN Pole Cap Assembly | 2 |
| MTS-HF-HD | H-Frame Assembly-HD | 2 |
| MTS-HD-Wing-24 | 24IN HD Wing | 4 |
| MTS-HD-Splice-57 | 57IN HD Splice | 4 |
| MTS-CLAMP-HOOK-4PK | Hook Clamp | 5 |

### Rail Bill of Materials

| Part | Qty |
|---|---|
| Rails (180in) | 10 |
| Rail Attachment | 20 |
| Module Mid Clamp | 30 |
| Module End Clamp | 20 |
| Ground Lug | 5 |

# Site Details:



**Site Address:** Smithfield Rd, Blacksburg, VA 24061, USA

### Array Specification

| | |
|---|---|
| **Duty Classification:** | HD |
| **Module Width:** | 44.60 in |
| **Module Length:** | 70.90in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 5 |
| **Total Number of Modules:** | 20 |
| **Winter Tilt Angle:** | 25 |
| **Front Edge Clearance:** | 10 |
| **Total Array Height at Tilt:** | 16.35 ft |
| **Total Frame Length:** | 28.50 ft |
| **Module Info/Notes:** | Canadian 450 |
| **Array Dimensions N/S:** | 15.03 ft |
| **Array Dimensions E/W:** | 29.96 ft |
| **Rail Length:** | 180.40 in |
| **Rail Spacing:** | 3.00 ft |

### Support Specifications

| | |
|---|---|
| **Pole Size:** | 6in Pipe Sch 80 |
| **Pole Length above Grade:** | 13.18 ft |
| **Number of Poles:** | 2 |
| **Pole Spacing:** | 17 ft |

### Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 6.75 ft<br>Pile 2: 6.75 ft |
| **Foundation Volume:** | 8.000 $y^3$ |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | Smithfield Rd, Blacksburg, VA 24061, USA |
| **Wind Speed:** | 115 mph |
| **Snow Load:** | 30 psf |

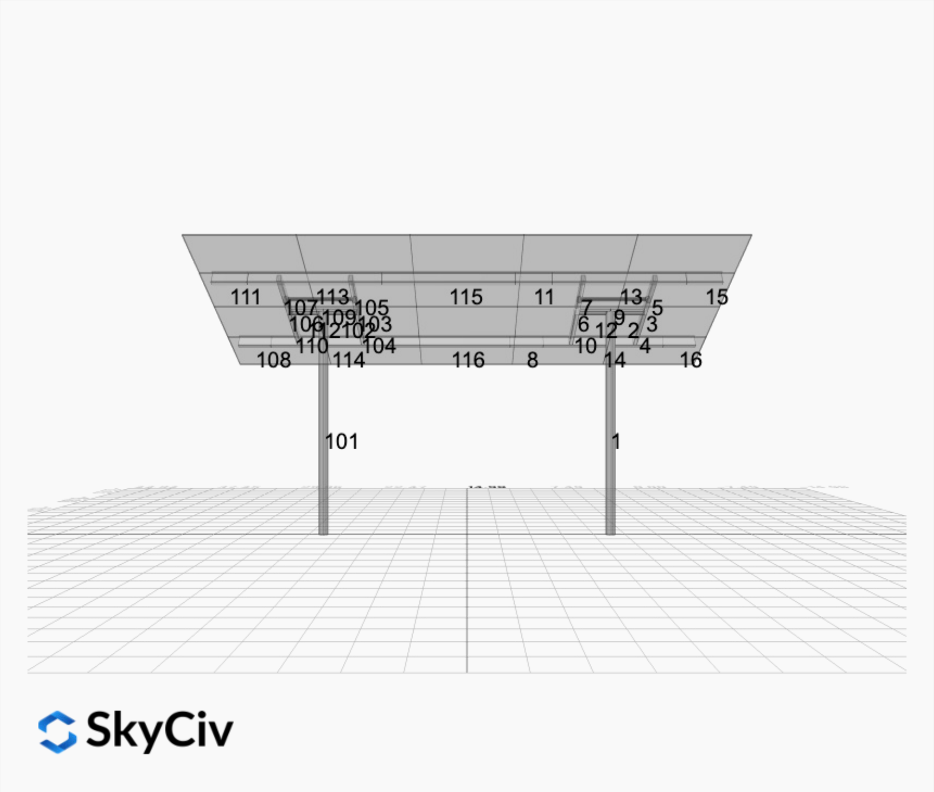
## Design Disclaimer

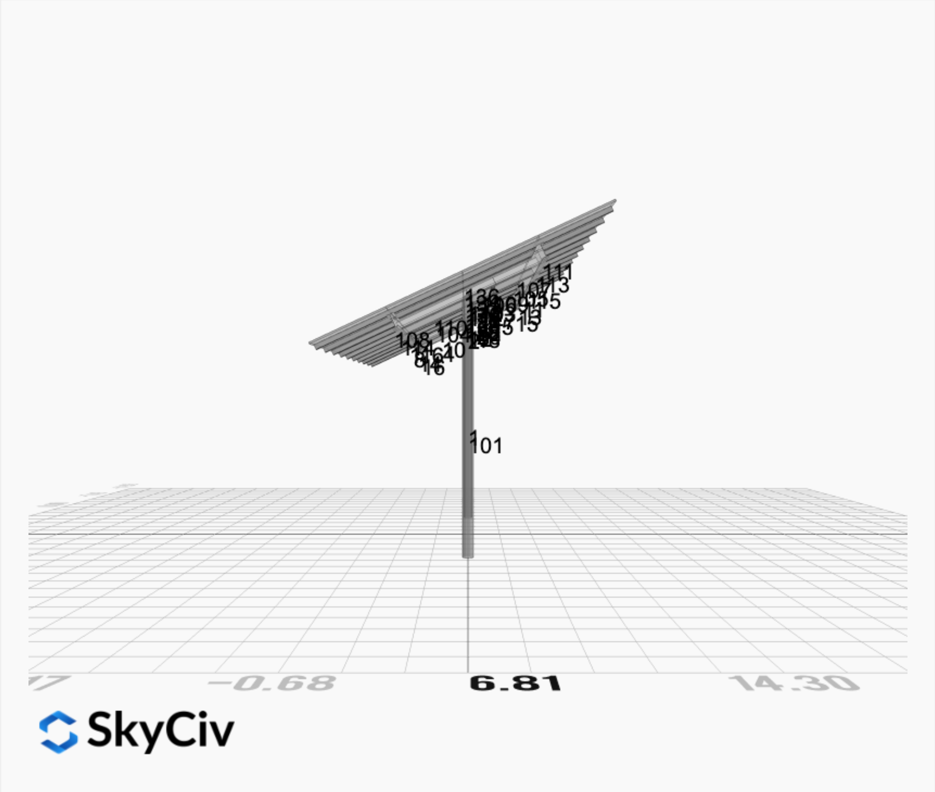
## AutoDesigner Input

```
{"wind_speed_override":115,"snow_load_override":30,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"orders@freecleansolar.com","designer_phone":"","project_id":"VA Tech - V1Jb","site_address":"Smithfield Rd, Blacksburg, VA 24061, USA","module_info":"Canadian
450","module_width":44.6,"module_length":70.9,"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":25,"ground_clearance":10,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}
```

**Design Notes:**

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)

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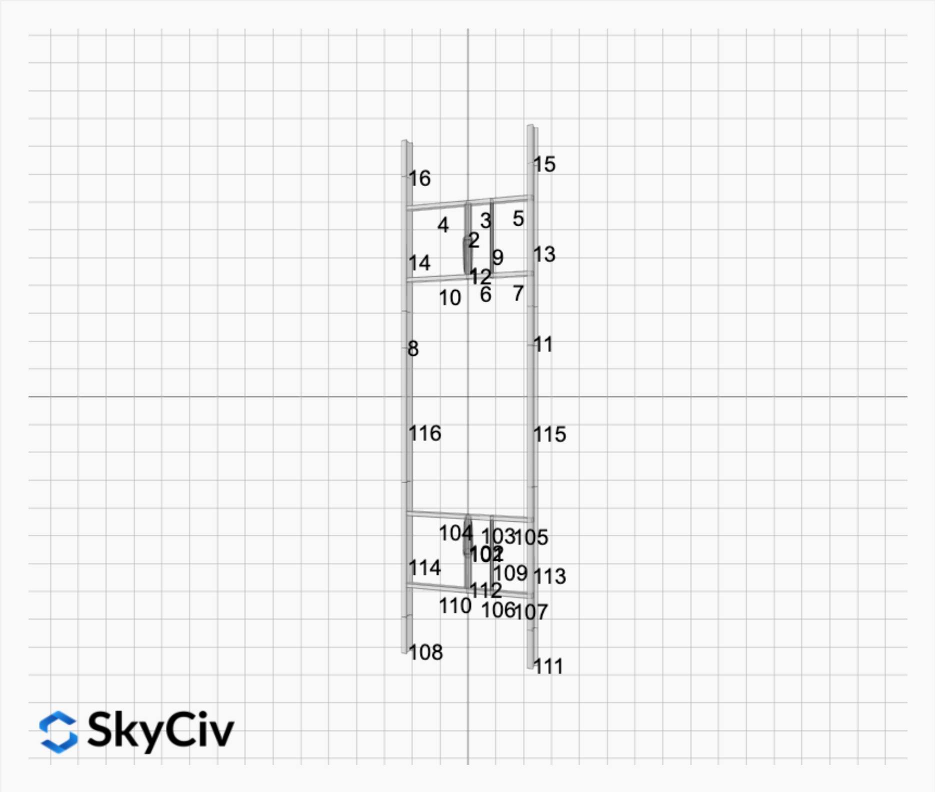
113
115
108
101
-0.68
6.81
14.30


16
15
4
3
5
2
14
9
13
12
10
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7
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11
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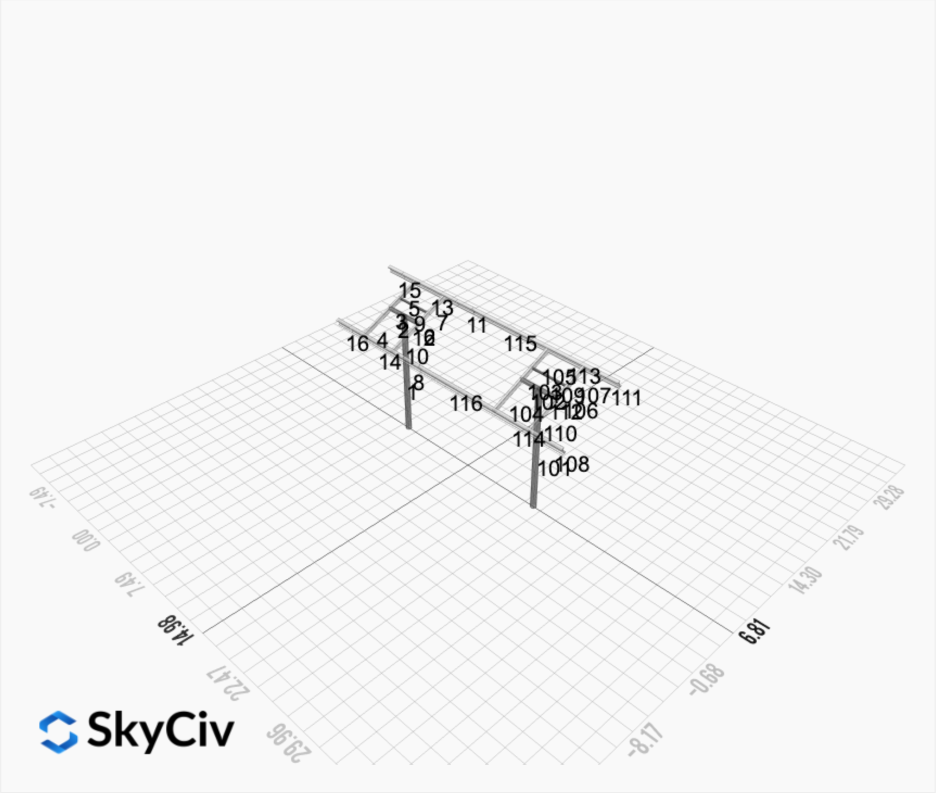
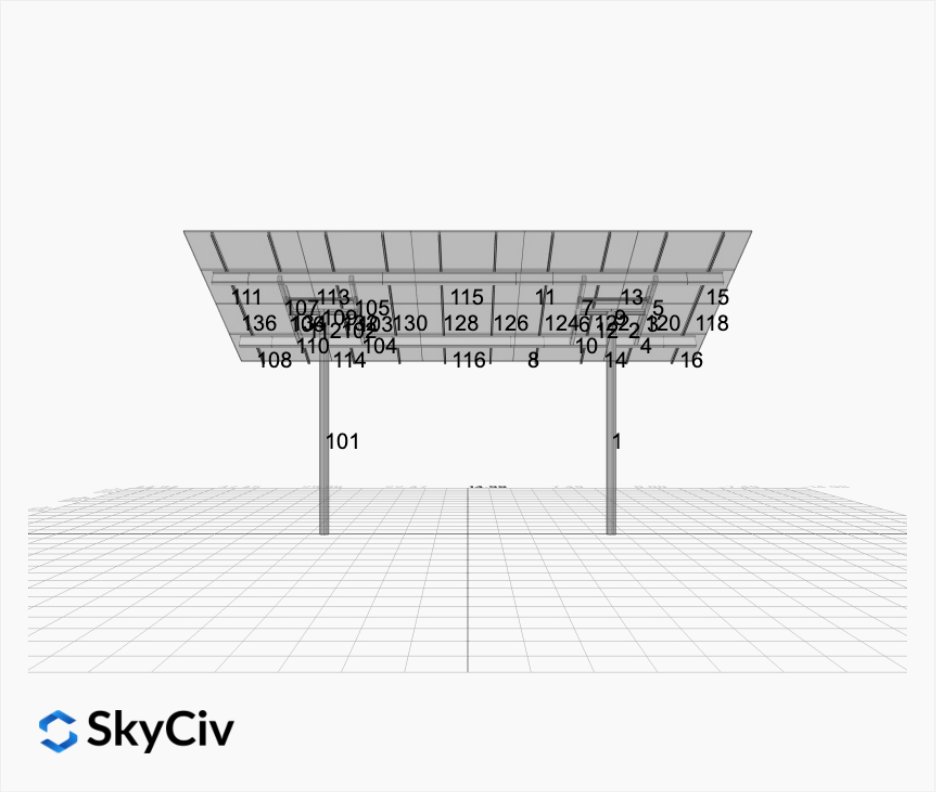
106
107
108
111


15
5
13
7
11
16
4
14
10
8
1
115
116
105
113
107
111
104
114
110
108
101
-7.49
0.00
7.49
14.98
22.47
29.96
29.28
21.79
14.30
6.81
-0.68
-8.17
SkyCiv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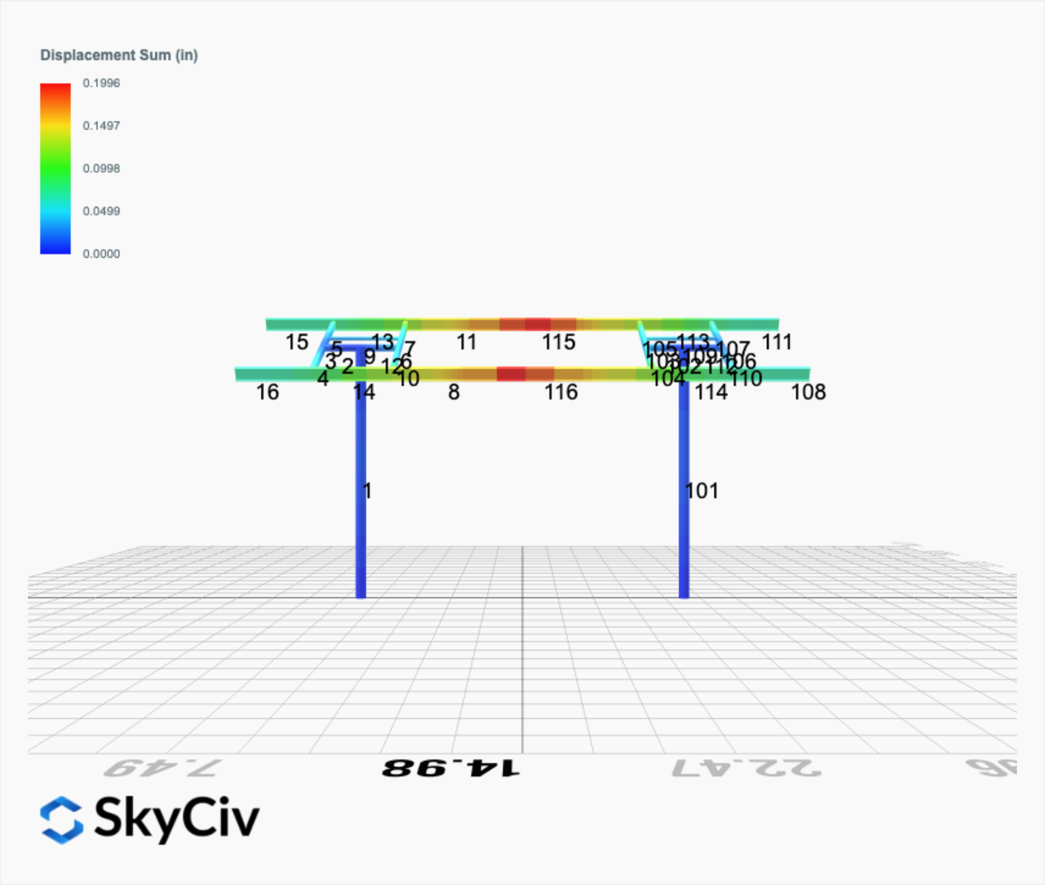
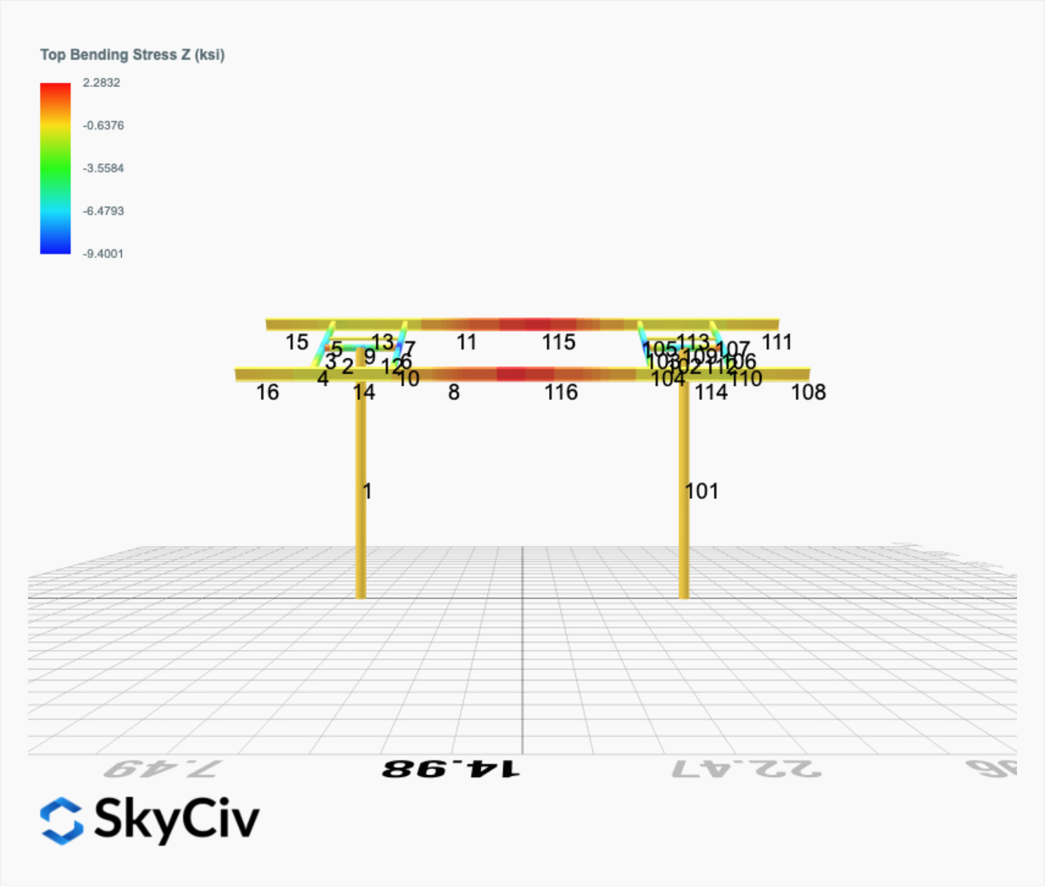
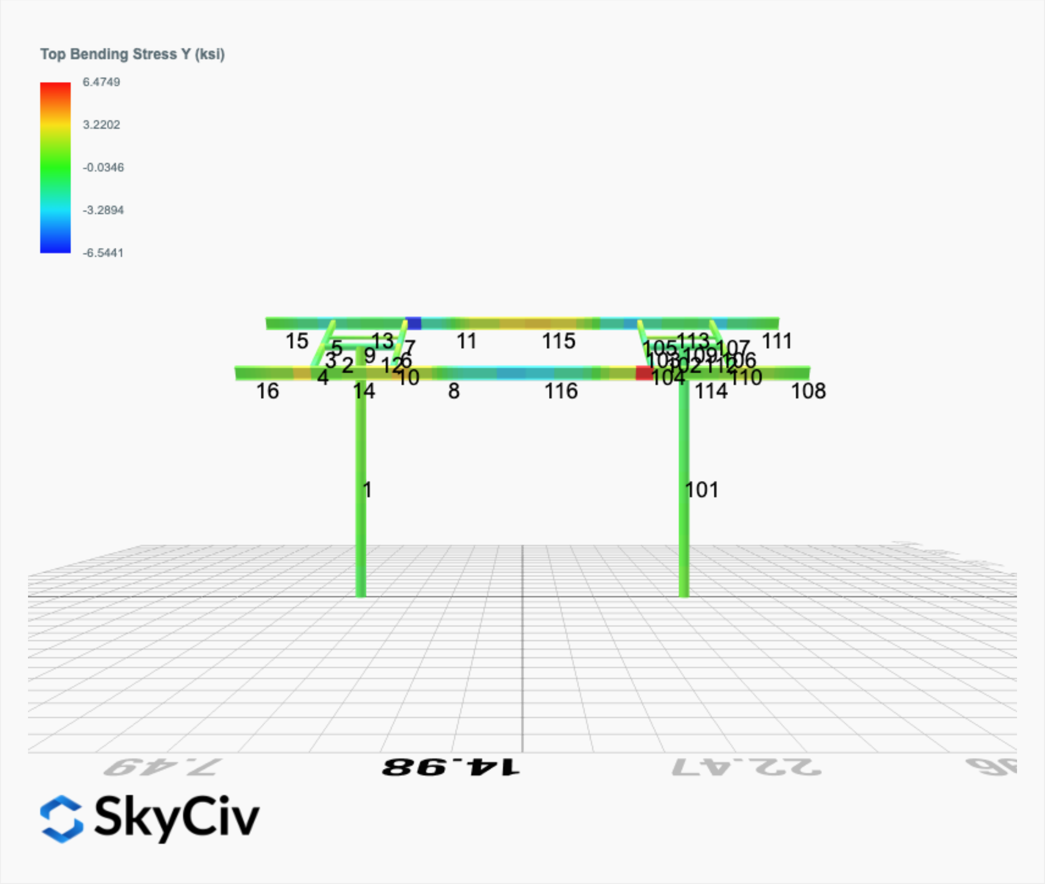
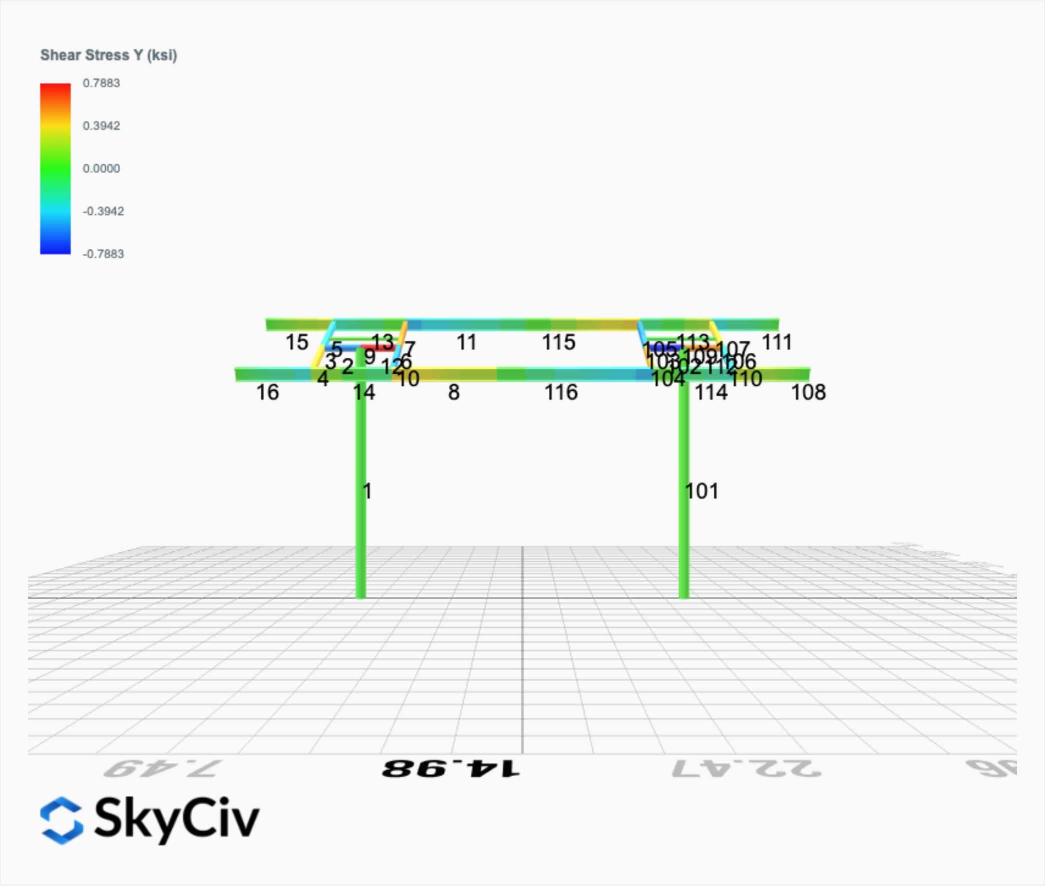
107
113
105
115
11
7
13
5
15
136
130
128
126
120
118
110
104
10
4
108
114
116
8
14
16
101
1
SkyCiv

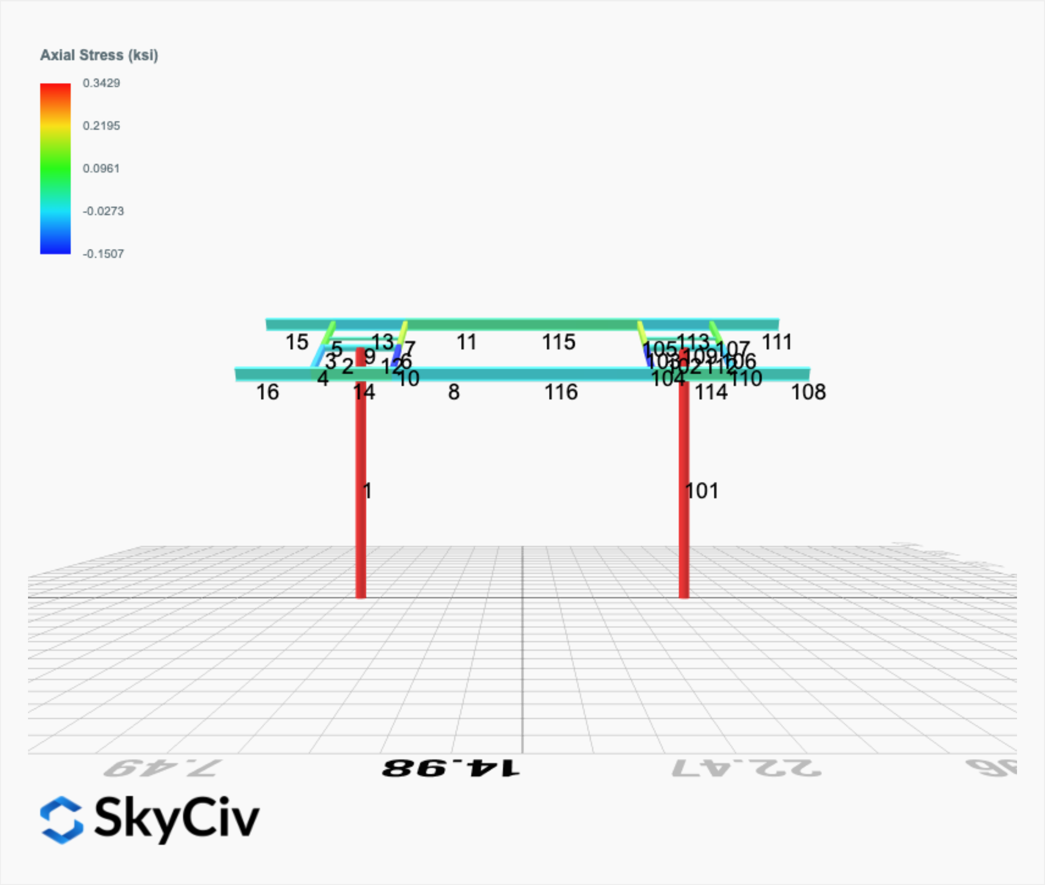
## FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
6.4749
3.2202
-0.0346
-3.2894
-6.5441
15
5
13
7
11
115
105
113
107
111
3
2
9
12
6
103
102
109
112
106
4
10
104
110
16
14
8
116
114
108
1
101
7.49
14.98
22.47
SkyCiv


Shear Stress Y (ksi)
0.7883
0.3942
0.0000
-0.3942
-0.7883
15
5
13
7
11
115
105
113
107
111
3
2
9
12
6
103
102
109
112
106
4
10
104
110
16
14
8
116
114
108
1
101
7.49
14.98
22.47
SkyCiv


Axial Stress (ksi)
0.3429
0.2195
0.0961
-0.0273
-0.1507
15
5
13
7
11
115
105
113
107
111
3
2
9
12
6
103
109
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
7.49
14.98
22.47

## 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 | 1.9264 | 0.0347 | 0.1465 | -0.0200 | 0.0271 |
| ULS: 2. D + L | 0.0000 | 1.9264 | 0.0347 | 0.1465 | -0.0200 | 0.0271 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 4.8086 | 0.1098 | 0.4645 | -0.0638 | 0.0353 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 1.9264 | 0.0347 | 0.1465 | -0.0200 | 0.0271 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 4.0881 | 0.0910 | 0.3850 | -0.0529 | 0.0332 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 1.9264 | 0.0347 | 0.1465 | -0.0200 | 0.0271 |
| ULS: 5b. D + 0.7E | 0.0000 | 1.9264 | 0.0347 | 0.1465 | -0.0200 | 0.0271 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0000 | 4.0881 | 0.0910 | 0.3850 | -0.0529 | 0.0332 |
| ULS: 8. 0.6D + 0.7E | 0.0000 | 1.1559 | 0.0208 | 0.0879 | -0.0120 | 0.0163 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.0580 | 6.3397 | 0.1617 | 0.6784 | -0.2156 | 29.0085 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.0580 | 6.3397 | 0.1617 | 0.6784 | -0.2156 | 29.0085 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.8007 | -1.9352 | -0.0760 | -0.3124 | 0.1507 | -22.3678 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 1.5436 | -1.3835 | -0.0612 | -0.2512 | 0.1283 | -29.0979 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5434 | 7.3980 | 0.1863 | 0.7839 | -0.1995 | 21.7693 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.5434 | 7.3980 | 0.1863 | 0.7839 | -0.1995 | 21.7693 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.3506 | 1.1919 | 0.0080 | 0.0408 | 0.0752 | -16.7629 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.1577 | 1.6056 | 0.0191 | 0.0867 | 0.0584 | -21.8105 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5435 | 5.2364 | 0.1300 | 0.5455 | -0.1667 | 21.7632 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.5435 | 5.2364 | 0.1300 | 0.5455 | -0.1667 | 21.7632 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.3506 | -0.9698 | -0.0483 | -0.1976 | 0.1080 | -16.7691 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.1577 | -0.5560 | -0.0372 | -0.1518 | 0.0913 | -21.8166 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.0580 | 5.5691 | 0.1479 | 0.6198 | -0.2076 | 28.9977 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.0580 | 5.5691 | 0.1479 | 0.6198 | -0.2076 | 28.9977 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.8007 | -2.7058 | -0.0898 | -0.3710 | 0.1587 | -22.3786 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 1.5435 | -2.1541 | -0.0751 | -0.3098 | 0.1364 | -29.1087 |

### 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 | 11.1083 |
| Shear X | -3.4300 |
| Shear Z | 0.2909 |
| Moment X | 1.2248 |
| Moment Y (Twist) | 0.3714 |
| Moment Z | 50.0051 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.3980 |
| Shear X | -2.0580 |
| Shear Z | 0.1863 |
| Moment X | 0.7839 |
| Moment Y (Twist) | 0.2156 |
| Moment Z | 29.1087 |

## 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 | 1.9265 | -0.0347 | -0.1462 | 0.0203 | 0.0275 |
| ULS: 2. D + L | -0.0000 | 1.9265 | -0.0347 | -0.1462 | 0.0203 | 0.0275 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 4.8088 | -0.1098 | -0.4633 | 0.0646 | 0.0365 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 1.9265 | -0.0347 | -0.1462 | 0.0203 | 0.0275 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 4.0882 | -0.0910 | -0.3840 | 0.0535 | 0.0342 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 1.9265 | -0.0347 | -0.1462 | 0.0203 | 0.0275 |
| ULS: 5b. D + 0.7E | -0.0000 | 1.9265 | -0.0347 | -0.1462 | 0.0203 | 0.0275 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 4.0882 | -0.0910 | -0.3840 | 0.0535 | 0.0342 |
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.1559 | -0.0208 | -0.0877 | 0.0122 | 0.0165 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.0581 | 6.3400 | -0.1617 | -0.6761 | 0.2163 | 29.0098 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.0581 | 6.3400 | -0.1617 | -0.6761 | 0.2163 | 29.0098 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.8008 | -1.9354 | 0.0760 | 0.3111 | -0.1509 | -22.3679 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 1.5435 | -1.3837 | 0.0612 | 0.2503 | -0.1275 | -29.1003 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5436 | 7.3983 | -0.1863 | -0.7815 | 0.2006 | 21.7709 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.5436 | 7.3983 | -0.1863 | -0.7815 | 0.2006 | 21.7709 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.3505 | 1.1918 | -0.0080 | -0.0411 | -0.0749 | -16.7623 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.1576 | 1.6056 | -0.0191 | -0.0867 | -0.0573 | -21.8116 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5435 | 5.2366 | -0.1300 | -0.5436 | 0.1673 | 21.7642 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.5435 | 5.2366 | -0.1300 | -0.5436 | 0.1673 | 21.7642 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.3506 | -0.9699 | 0.0483 | 0.1968 | -0.1081 | -16.7691 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.1576 | -0.5561 | 0.0372 | 0.1512 | -0.0906 | -21.8184 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.0580 | 5.5694 | -0.1479 | -0.6176 | 0.2082 | 28.9988 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.0580 | 5.5694 | -0.1479 | -0.6176 | 0.2082 | 28.9988 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.8008 | -2.7059 | 0.0898 | 0.3696 | -0.1590 | -22.3789 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 1.5435 | -2.1542 | 0.0751 | 0.3088 | -0.1357 | -29.1113 |

### 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 | 11.1087 |
| Shear X | -3.4301 |
| Shear Z | -0.2909 |
| Moment X | -1.2206 |
| Moment Y (Twist) | 0.3724 |
| Moment Z | 50.0100 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.3983 |
| Shear X | -2.0581 |
| Shear Z | -0.1863 |
| Moment X | -0.7815 |
| Moment Y (Twist) | 0.2163 |
| Moment Z | 29.1113 |

# Project Details

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

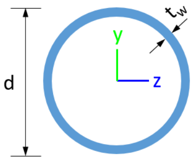
User Name: sales@mtsolar.us
Unit System: imperial

# Design Input Information

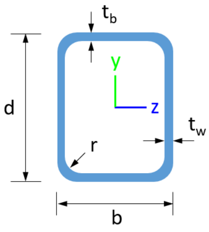
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

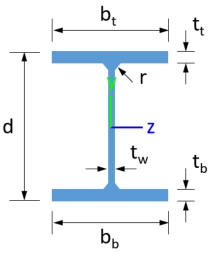
**Section Dimensions**



| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | | |
| 8 | 6in Pipe Sch 80 | 6.63 | 0.43 | | | | | |



| 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 |
| 8 | 6in Pipe Sch 80 | 8.40 | 80.98 | 40.49 | 40.49 | 0.00 | 16.60 | 16.60 |
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 0.73 | 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 | 8 | 27.67 | 27.67 | 13.18 | - | 300 | 200 | 1 |
| 2 | 5 | 4.20 | 4.20 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.26,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,2.40,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.58 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.79,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.22,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.72,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 1.27,1.27,1.27,1.27,1.27,1.27,1.27,1.27,1.27,1.42,1.27,1.27,1.27,1.07,1.27,1.27,1.28,1.29,1.27,1.27,1.27,1.40,1.27,1.27,1.27,1.15 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.56,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.63 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 1.28,1.28,1.28,1.28,1.28,1.28,1.27,1.27,1.27,1.28,1.27,1.27,1.27,1.28,1.27,1.27,1.28,1.21,1.27,1.27,1.27,1.28,1.27,1.27,1.27,1.28 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.26,1.26,1.26,1.26,1.26,1.26,1.27,1.27,1.28,1.34,1.27,1.27,1.27,1.33,1.27,1.27,1.25,1.16,1.27,1.27,1.28,1.35,1.27,1.27,1.27,1.33 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.25,1.25,1.25,1.25,1.25,1.25,1.26,1.26,1.28,2.50,1.26,1.26,1.27,1.24,1.26,1.26,1.23,1.30,1.26,1.26,1.28,2.31,1.26,1.26,1.27,1.16 | 300 | 200 | 1 |
| 15 | 19 | 4.20 | 4.20 | 2.00 | 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 | 4.20 | 4.20 | 2.00 | 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 | 8 | 27.67 | 27.67 | 13.18 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.22,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.56,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.63 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.72,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.26,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.79,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 108 | 19 | 4.20 | 4.20 | 2.00 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.69,1.67,1.67,1.66,2.36,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.71,1.67,1.67,1.66,1.58 | 300 | 200 | 1 |
| 111 | 19 | 4.20 | 4.20 | 2.00 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 112 | 5 | 4.20 | 4.20 | 2.00 | - | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.26,1.26,1.26,1.26,1.26,1.26,1.27,1.27,1.28,1.34,1.27,1.27,1.27,1.33,1.27,1.27,1.25,1.16,1.27,1.27,1.28,1.35,1.27,1.27,1.27,1.33 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.25,1.25,1.25,1.25,1.25,1.25,1.26,1.26,1.28,2.51,1.26,1.26,1.27,1.24,1.26,1.26,1.23,1.30,1.26,1.26,1.28,2.31,1.26,1.26,1.27,1.16 | 300 | 200 | 1 |
| 115 | 19 | 4.84 | 4.84 | 7.45 | 1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.10,1.09,1.09,1.10,1.08,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.10 | 300 | 200 | 1 |
| 116 | 19 | 7.45 | 7.45 | 7.45 | 1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.12,1.09,1.09,1.09,1.03,1.09,1.09,1.10,1.10,1.09,1.09,1.09,1.12,1.09,1.09,1.09,1.06 | 300 | 200 | 1 |

## Member Design Capacity

| **Member ID** | **$\Phi_t P_n$ (kip)** | **$\Phi_c P_n$ (kip)** | **$\Phi_b M_{zn}$ (k-ft)** | **$\Phi_b M_{yn}$ (k-ft)** | **$\Phi_v V_{yn}$ (kip)** | **$\Phi_v V_{zn}$ (kip)** |
|---|---|---|---|---|---|---|
| 1 | 378.22 | 82.96 | 62.23 | 62.23 | 113.47 | 113.47 |
| 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 | 123.95 | 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 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 85.85 | 26.57 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 85.85 | 26.67 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 102.39 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 102.39 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 378.22 | 82.96 | 62.23 | 62.23 | 113.47 | 113.47 |
| 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 | 102.39 | 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 | 102.39 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 182.14 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 85.85 | 26.54 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 85.85 | 26.64 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 86.20 | 24.84 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 58.22 | 23.76 | 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 | 0.134 | 0.804 | 0.042 | 0.030 | 0.003 | 0.887 | #13 | 0.756 | Not Required | Pass |
| 2 | 0.001 | 0.356 | 0.142 | 0.080 | 0.028 | 0.499 | #13 | 0.171 | Not Required | Pass |
| 3 | 0.005 | 0.607 | 0.027 | 0.060 | 0.006 | 0.616 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.004 | 0.589 | 0.051 | 0.059 | 0.013 | 0.627 | #13 | 0.080 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.005 | 0.377 | 0.038 | 0.060 | 0.009 | 0.379 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.007 | 0.720 | 0.067 | 0.073 | 0.019 | 0.760 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.007 | 0.446 | 0.088 | 0.072 | 0.022 | 0.460 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.002 | 0.146 | 0.062 | 0.044 | 0.010 | 0.192 | #21 | 0.095 | Not Required | Pass |
| 9 | 0.001 | 0.070 | 0.052 | 0.002 | 0.002 | 0.114 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.008 | 0.700 | 0.083 | 0.070 | 0.019 | 0.714 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.003 | 0.148 | 0.061 | 0.046 | 0.010 | 0.191 | #21 | 0.095 | Not Required | Pass |
| 12 | 0.001 | 0.475 | 0.159 | 0.099 | 0.030 | 0.634 | #13 | 0.053 | Not Required | Pass |
| 13 | 0.004 | 0.118 | 0.205 | 0.062 | 0.014 | 0.265 | #21 | 0.286 | Not Required | Pass |
| 14 | 0.003 | 0.118 | 0.202 | 0.061 | 0.014 | 0.258 | #21 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.024 | 0.030 | 0.019 | 0.004 | 0.051 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.023 | 0.030 | 0.019 | 0.004 | 0.051 | #21 | Not Required | Not Required | Pass |
| 101 | 0.134 | 0.804 | 0.042 | 0.030 | 0.003 | 0.887 | #13 | 0.756 | Not Required | Pass |
| 102 | 0.001 | 0.475 | 0.159 | 0.099 | 0.030 | 0.634 | #13 | 0.053 | Not Required | Pass |
| 103 | 0.007 | 0.721 | 0.067 | 0.073 | 0.019 | 0.761 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.008 | 0.701 | 0.083 | 0.070 | 0.019 | 0.714 | #13 | 0.080 | Not Required | Pass |
| 105 | 0.007 | 0.447 | 0.088 | 0.072 | 0.022 | 0.460 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.005 | 0.607 | 0.027 | 0.060 | 0.006 | 0.616 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.005 | 0.377 | 0.038 | 0.060 | 0.009 | 0.379 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.000 | 0.023 | 0.030 | 0.019 | 0.004 | 0.051 | #21 | Not Required | Not Required | Pass |
| 109 | 0.001 | 0.070 | 0.052 | 0.002 | 0.002 | 0.115 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.004 | 0.589 | 0.051 | 0.059 | 0.013 | 0.627 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.000 | 0.024 | 0.030 | 0.019 | 0.004 | 0.051 | #21 | Not Required | Not Required | Pass |
| 112 | 0.001 | 0.356 | 0.142 | 0.080 | 0.028 | 0.499 | #13 | 0.171 | Not Required | Pass |
| 113 | 0.004 | 0.118 | 0.205 | 0.062 | 0.014 | 0.265 | #21 | 0.190 | Not Required | Pass |
| 114 | 0.003 | 0.118 | 0.202 | 0.061 | 0.014 | 0.258 | #21 | 0.286 | Not Required | Pass |
| 115 | 0.004 | 0.249 | 0.115 | 0.046 | 0.010 | 0.336 | #21 | 0.346 | Not Required | Pass |
| 116 | 0.002 | 0.245 | 0.116 | 0.044 | 0.010 | 0.335 | #21 | 0.532 | 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/comression) |
| $M_n$ | Nominal flexural strength (about Z/Y axis) |
| $V_n$ | Nominal shear strength (along Z/Y axis) |
| P | Design ratio in case of axial force |
| $M_z$ | Design ratio in case of bending about Z axis |
| $M_y$ | Design ratio in case of bending about Y axis |
| $V_y$ | Design ratio in case of shear along Y axis |
| $V_z$ | Design ratio in case of shear along Z axis |

| | |
|---|---|
| $(P,M_z,M_y)$ | Design ratio in case of axial force and bending action |
| KL/r | Design ratio in case of section slenderness |
| δ | Design ratio in case of member deflection |
| OK | Capacity is provided |
| NG | Capacity is not provided |

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

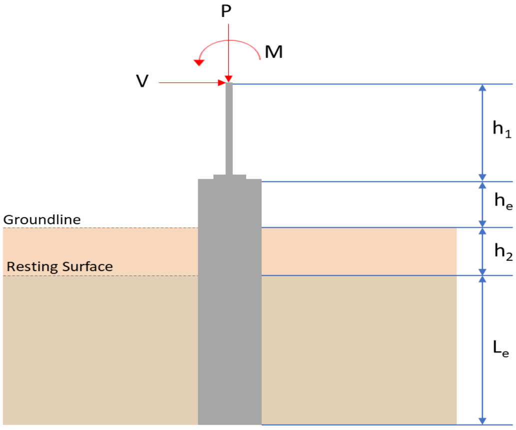
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input



**Geometry**

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 6.75$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.398 | 11.108 |
| $V_x$ (kip) | -2.058 | -3.430 |
| $V_z$ (kip) | 0.186 | 0.291 |
| $M_x$ (kipft) | 0.784 | 1.225 |
| $M_z$ (kipft) | 29.109 | 50.005 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.058\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.32771\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(29.109\ \text{kipft}) + ((-2.058\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.6352\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2775\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.186\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.029618\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.784\ \text{kipft}) + ((0.186\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.12484\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.4273\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.2775\ \text{ft}), (2.4273\ \text{ft})]$$

$$L_{e,req} = 6.278\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.278\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.93007$$

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

### End-bearing Capacity (ASD)

$A$ - Pile cross-section area

$$A = b\ D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.398\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.46238\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46238\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23119$$

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

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*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.32771\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.6352\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6352\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (4.6352\ \mathrm{kipft/ft})) + (4 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6358\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6352\ \mathrm{kipft/ft})) + (3 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (4.6352\ \mathrm{kipft/ft})) + (2 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.24604\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.6352\ \mathrm{kipft/ft})) + ((-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.9295\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6358\ \mathrm{ft})}{2}$$

$$p_a = 0.34768\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24604\ \mathrm{kip/ft^2}\right)}{\left(0.34768\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.70767$$

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

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

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.9295\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91802$$

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

**Considering z-direction:**

$H_o = 0.029618\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.12484\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.12484\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.12484\ \mathrm{kipft/ft})) + (4 \times (0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7904\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.12484\ \mathrm{kipft/ft})) + (3 \times (0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.12484\ \mathrm{kipft/ft})) + (2 \times (0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.02568\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.12484\ \mathrm{kipft/ft})) + ((0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.059207\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7904\ \mathrm{ft})}{2}$$

$$p_a = 0.35928\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.02568\ \mathrm{kip/ft^2}\right)}{\left(0.35928\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.071477$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

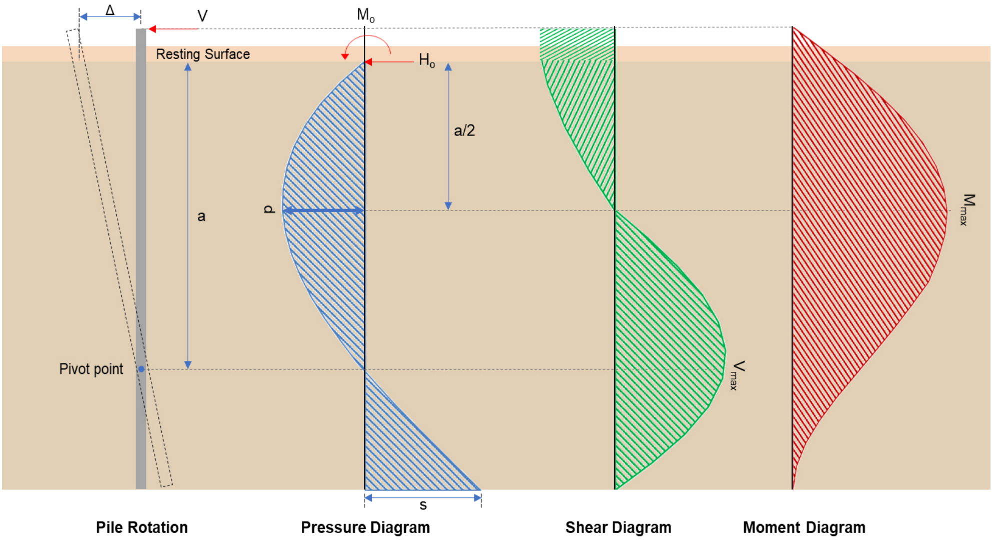
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.059207\ \mathrm{kip/ft^2})}{(1.0125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.058476$$

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



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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-3.43\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.54618\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(50.005\ \mathrm{kipft}) + ((-3.43\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.9626\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(7.9626\ \mathrm{kipft/ft})}{(-0.54618\ \mathrm{kip/ft})}$$

$$E = 14.579\ \mathrm{ft}$$

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

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

$$(4 \times (7.9626\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.54618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)$$

$$a = \frac{\quad}{(6 \times (7.9626\ \mathrm{kipft/ft})) + (4 \times (-0.54618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6327\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.54618\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.579\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.579\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.793\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.54618\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(14.579\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.579\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.579\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.709\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.291\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.046338\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.225\ \mathrm{kipft}) + ((0.291\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.19506\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.19506\ \mathrm{kipft/ft})}{(0.046338\ \mathrm{kip/ft})}$$

$$E = 4.2096\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.19506\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.046338\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.19506\ \mathrm{kipft/ft})) + (4 \times (0.046338\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7906\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.046338\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.2096\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7906\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.2096\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7906\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.32764\ \text{kip}$$

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

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

$$M_{max} = ((0.046338\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(4.2096\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.7906\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.2096\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7906\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.2096\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7906\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.99383\ \text{kipft}$$

---

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.108\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.227\ \text{in}^2$$

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

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

$$A_{min} = Max\left[(-84.227\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(11.108\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0041522$$

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

---

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

**Parameters:**

$b_w = 48\ \text{in}$ - Effective width,
22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.108 \text{ kip} \rightarrow 11108 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11108 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.97 \text{ kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.97 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.97 \text{ kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

*22.5.1.1* $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.06 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 9.793 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.793\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.088179$$

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

**Considering z-direction:**

$V_{max} = 0.32764\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.32764\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.0029501$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$

$$\phi M_{n,1} = 249.600kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$

$$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$

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

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

$$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$

$$\phi M_n = 249.6\ \mathrm{kipft}$$

**Considering x-direction:**

$M_{max} = 31.709\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(31.709\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.12704$$

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

**Considering z-direction:**

$M_{max} = 0.99383\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

|  |  |  |
|---|---|---|
|  | $$Ratio = \frac{(0.99383\ \text{kipft})}{(249.6\ \text{kipft})}$$<br>$$Ratio = 0.0039817$$ | Status: **PASS**<br>Ratio: **0.000** |

**REFERENCES** | **CALCULATIONS** | **RESULTS**

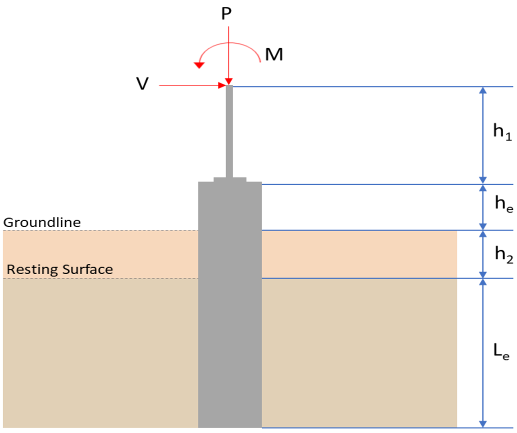
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input



**Geometry**

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.75\ \mathrm{ft}$ - 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 $(q_a)$ $(\mathrm{psf})$ | 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) | 7.398 | 11.109 |
| $V_x$ (kip) | -2.058 | -3.430 |
| $V_z$ (kip) | -0.186 | -0.291 |
| $M_x$ (kipft) | -0.781 | -1.221 |
| $M_z$ (kipft) | 29.111 | 50.010 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.058\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.32771\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(29.111\ \text{kipft}) + ((-2.058\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.6355\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2777\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.186\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.029618\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.781\ \text{kipft}) + ((-0.186\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.12436\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.877\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.2777\ \text{ft}), (1.877\ \text{ft})]$$

$$L_{e,req} = 6.278\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.278\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.93007$$

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

## End-bearing Capacity (ASD)

$A$ - Pile cross-section area

$$A = b\ D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.398\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.46238\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46238\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23119$$

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

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*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.32771\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.6355\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6355\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (4.6355\ \mathrm{kipft/ft})) + (4 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6358\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6355\ \mathrm{kipft/ft})) + (3 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (4.6355\ \mathrm{kipft/ft})) + (2 \times (-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.24607\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.6355\ \mathrm{kipft/ft})) + ((-0.32771\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.92958\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6358\ \mathrm{ft})}{2}$$

$$p_a = 0.34768\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24607\ \mathrm{kip/ft^2}\right)}{\left(0.34768\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.70775$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.92958\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9181$$

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

**Considering z-direction:**

$H_o = -0.029618\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.12436\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.12436\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.12436\ \mathrm{kipft/ft})) + (4 \times (-0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.791\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.12436\ \mathrm{kipft/ft})) + (3 \times (-0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.12436\ \mathrm{kipft/ft})) + (2 \times (-0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.0064407\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.12436\ \mathrm{kipft/ft})) + ((-0.029618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.0064271\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.791\ \mathrm{ft})}{2}$$

$$p_a = 0.35932\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0064407\ \mathrm{kip/ft^2}\right)}{\left(0.35932\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.017924$$

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

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

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$

$$p_s = 1.0125 \text{ kip/ft}^2$$

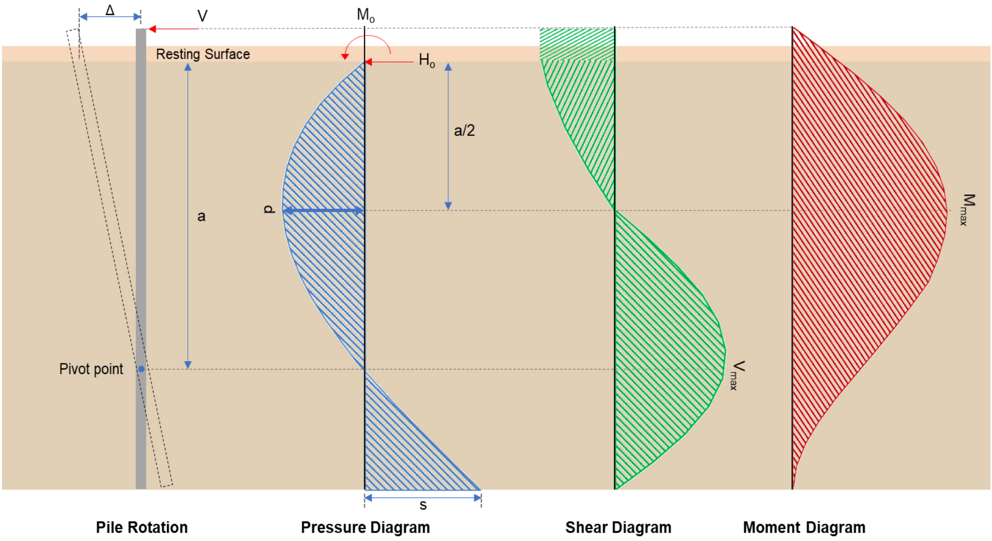
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0064271 \text{ kip/ft}^2\right)}{\left(1.0125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0063477$$

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



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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-3.43 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.54618 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(50.01 \text{ kipft}) + ((-3.43 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.9634 \text{ kipft/ft}$$

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

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

$$E = \frac{(7.9634 \text{ kipft/ft})}{(-0.54618 \text{ kip/ft})}$$

$$E = 14.58 \text{ ft}$$

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

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

$$(4 \times (7.9634 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.54618 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)$$

$$a = \frac{\phantom{x}}{(6 \times (7.9634\ \mathrm{kipft/ft})) + (4 \times (-0.54618\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6327\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.54618\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.58\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.58\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{(6.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.794\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.54618\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[\left(\frac{(14.58\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.58\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.58\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.6327\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.712\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.291\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.046338\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.221\ \mathrm{kipft}) + ((-0.291\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.19443\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.19443\ \mathrm{kipft/ft})}{(-0.046338\ \mathrm{kip/ft})}$$

$$E = 4.1959\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.19443\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.046338\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.19443\ \mathrm{kipft/ft})) + (4 \times (-0.046338\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7911\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.046338\ \text{kip/ft}) \times (48\ \text{in})) \times \Bigg[1 - \Bigg[3 \times \left(\frac{4 \times (4.1959\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7911\ \text{ft})}{(6.75\ \text{ft})}\right)^2\Bigg] + \Bigg[4 \times \left(\frac{3 \times (4.1959\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7911\ \text{ft})}{(6.75\ \text{ft})}\right)^3\Bigg]\Bigg]$$

$$V_{max} = 0.32697\ \text{kip}$$

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

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

$$M_{max} = ((-0.046338\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \Bigg[\left(\frac{(4.1959\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.7911\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \Bigg[\left(\frac{4 \times (4.1959\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.7911\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\Bigg] + \Bigg[\left(\frac{3 \times (4.1959\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.7911\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\Bigg]\Bigg]$$

$$M_{max} = 0.9916\ \text{kipft}$$

---

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.109\ \text{kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.227\ \text{in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.227\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

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

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

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

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

**Ties:**

25.7.2.2 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)

25.7.2.1 $s_{ties}$ - Maximum spacing of ties,

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.109\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0041526$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$ , $P = 11.109\ \text{kip} \rightarrow 11109\ \text{lbf}$ ,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11109\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.97\ \text{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.97\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.97\ \text{kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

*22.5.1.1* $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.97\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.06\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 9.794\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.794\ \text{kip})}{(111.06\ \text{kip})}$$

$$Ratio = 0.088186$$

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

**Considering z-direction:**

$V_{max} = 0.32697\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.32697\ \text{kip})}{(111.06\ \text{kip})}$$

$$Ratio = 0.0029441$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$

$$\phi M_{n,1} = 249.600 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$

$$\phi M_{n,2} = 2121.6\ \text{kipft}$$

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

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

$$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$

$$\phi M_n = 249.6\ \text{kipft}$$

**Considering x-direction:**

$M_{max} = 31.712\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(31.712\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.12705$$

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

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**Considering z-direction:**

$M_{max} = 0.9916\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $Ratio = \frac{(0.9916 \text{ kipft})}{(249.6 \text{ kipft})}$<br>$Ratio = 0.0039728$ | Status: **PASS**<br>Ratio: **0.000** |