# Your Project Calculations

Project Name: G, CJ Anderson 8k upgrade

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=G,%20CJ%20Anderson%208k%20upgrade&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=RdljfrB0TMbNraZ1zQjvQCPkcAseeXluBbyix6hEL0KsTbgT02lhzqv4B6Tu1OeU

## Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 1P-0-8TOP-HD-57-L-5Hx3W-G16L |
| **Duty Classification:** | HD |
| **Module Width:** | 41.00 in |
| **Module Length:** | 75.00in |
| **Number of Rows:** | 5 |
| **Number of Columns:** | 3 |
| **Total Number of Modules:** | 15 |
| **Desired Tilt Angle:** | 30 |
| **Front Edge Clearance:** | 6 |
| **Total Array Height at Tilt:** | 14.59 ft |
| **Total Frame Length:** | 17.00 ft |
| **Frame Weight:** | 1138 lbs |
| **Array Dimensions N/S:** | 17.29 ft |
| **Array Dimensions E/W:** | 19.00 ft |
| **Rail Length:** | 207.50 in |
| **Rail Spacing:** | 3.13 ft |
| **Rail Check:** | Not Checked |

## Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 40 |
| **Pole Length above Grade:** | 10.32 ft |
| **Number of Poles:** | 1 |
| **Pole Spacing:** | 0 |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 6.50 ft |
| **Foundation Volume:** | 3.852 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.000002 kip |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 28518 W Pipestem Rd, Fort Grant, AZ 85643, USA |
| **Wind Speed:** | 96 mph |
| **Snow Load:** | 5 psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.002199 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":"G, CJ
Anderson 8k upgrade","site_address":"28518 W Pipestem Rd, Fort Grant, AZ 85643,
USA","module_width":41,"module_length":75,"number_rows":"5","number_columns":3,"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":30,"ground_clearance":6,"risk_category":"I","exposure_category":"C","frame_duty_overri
de":"auto","pole_override":"8_40","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foun
dation_size":48,"check_rails":false}
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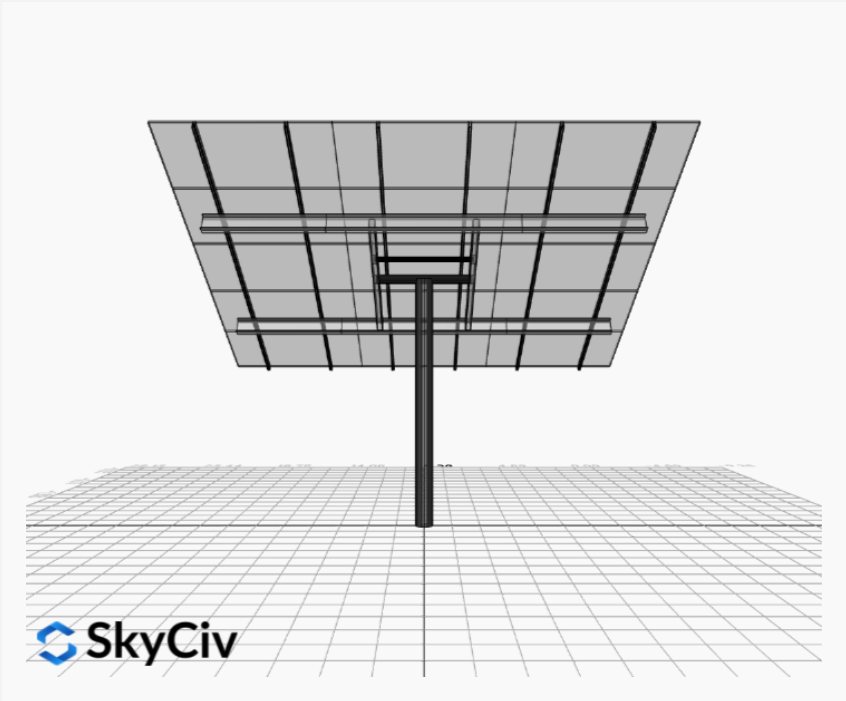
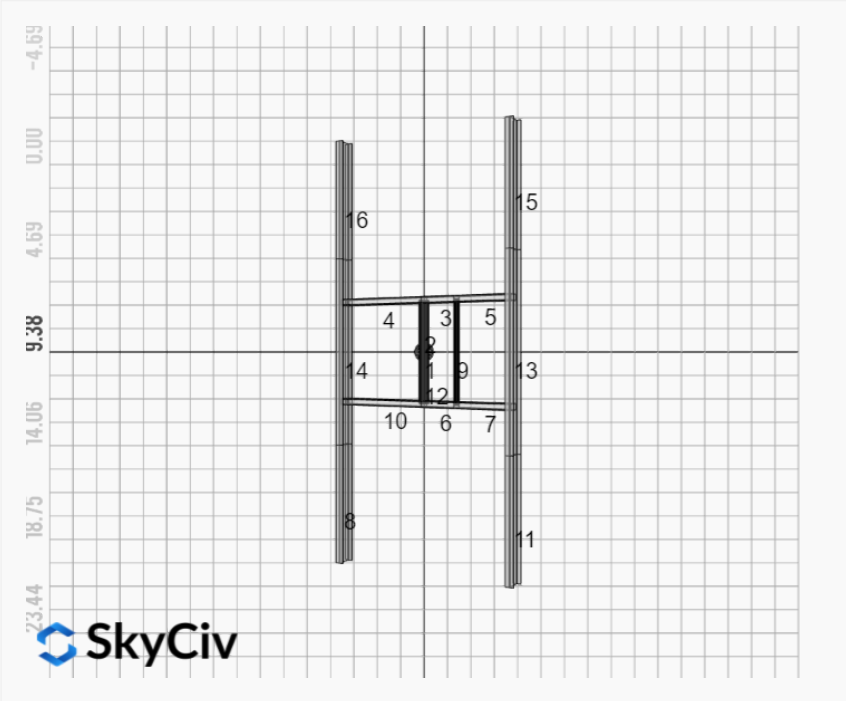
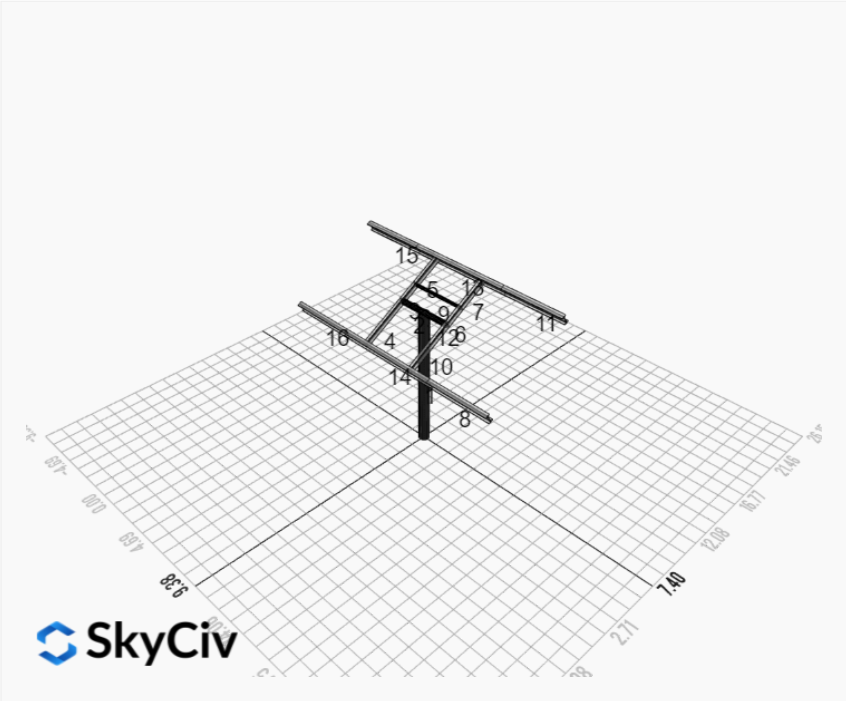
**Design Notes:**

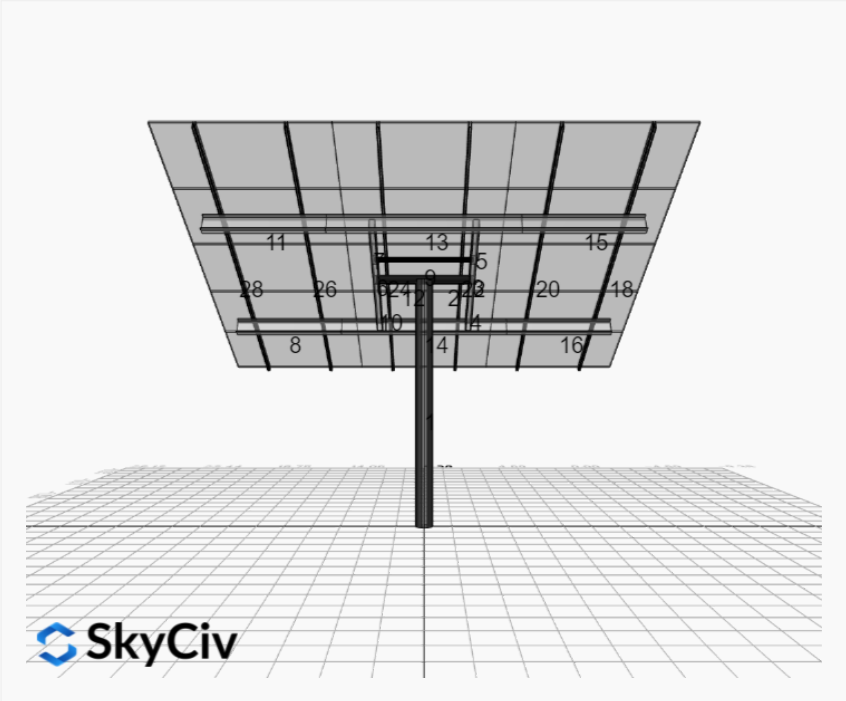
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



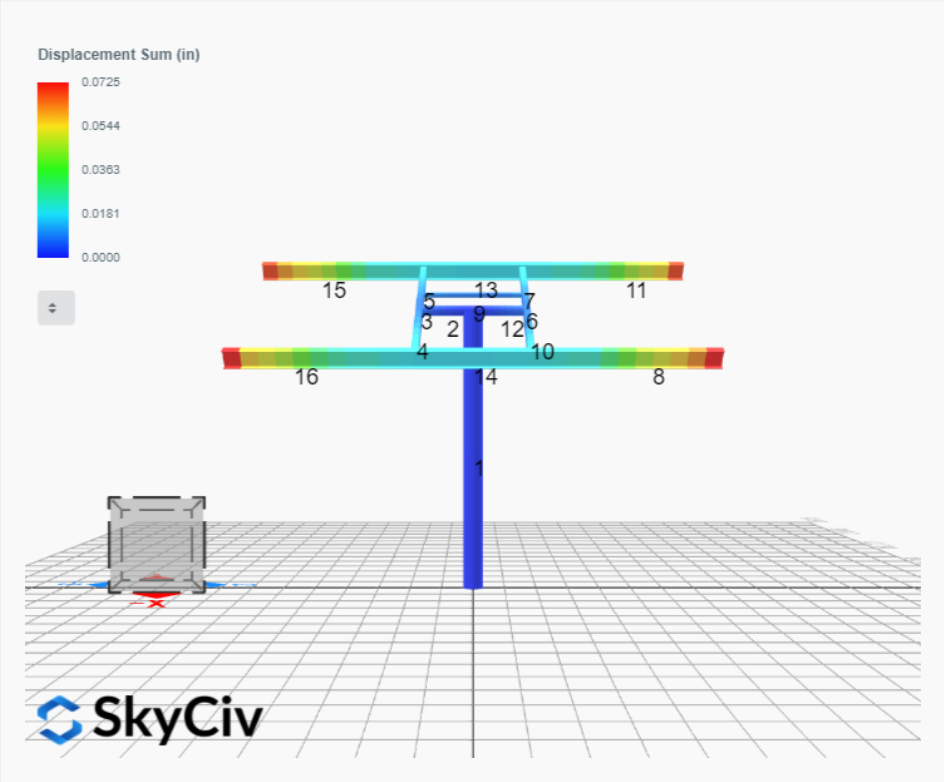
SkyCiv

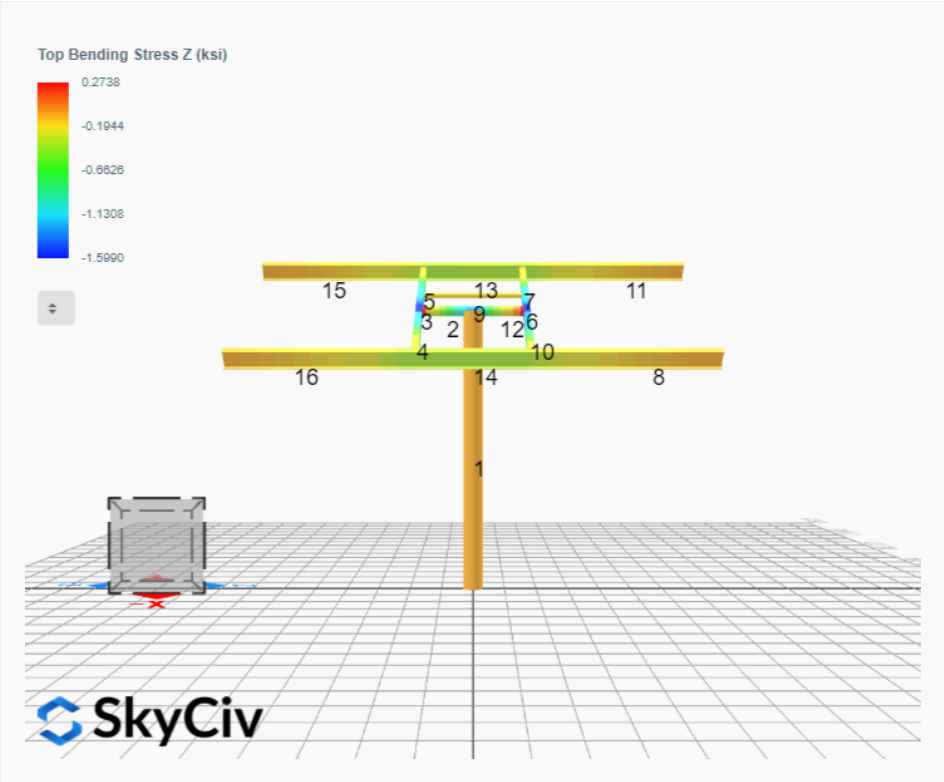

-4.69
0.00
4.69
9.38
14.06
18.75
23.44
16
15
4
3
5
2
14
1
9
13
12
10
6
7
8
11
SkyCiv

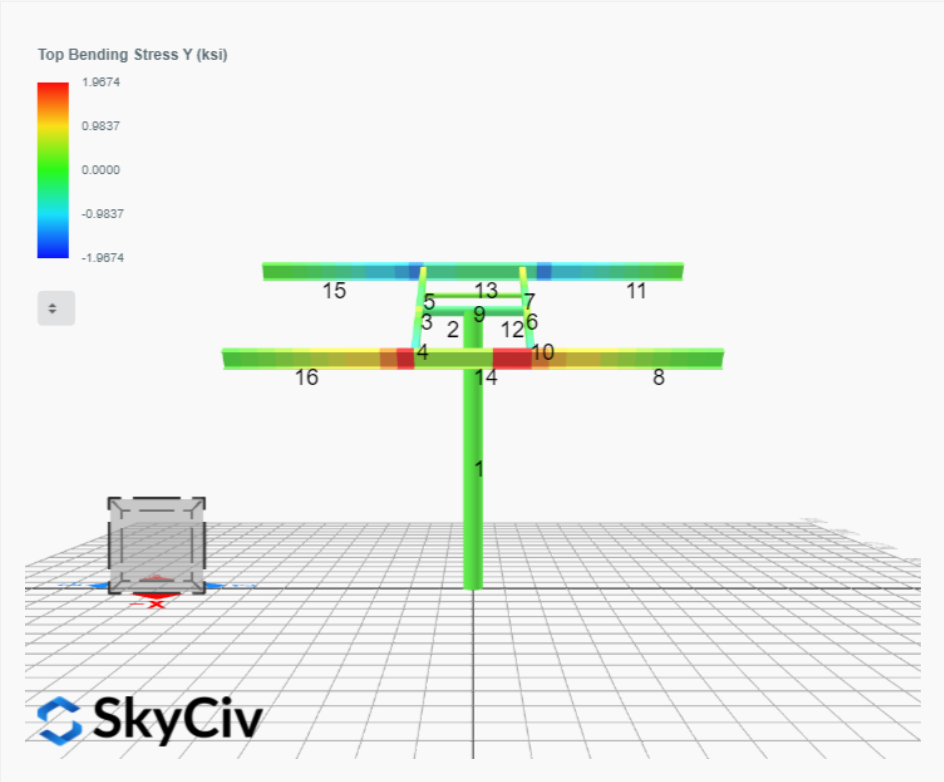

15
5
12
9
7
11
16
4
12
6
14
10
8
9.38
7.40
SkyCiv

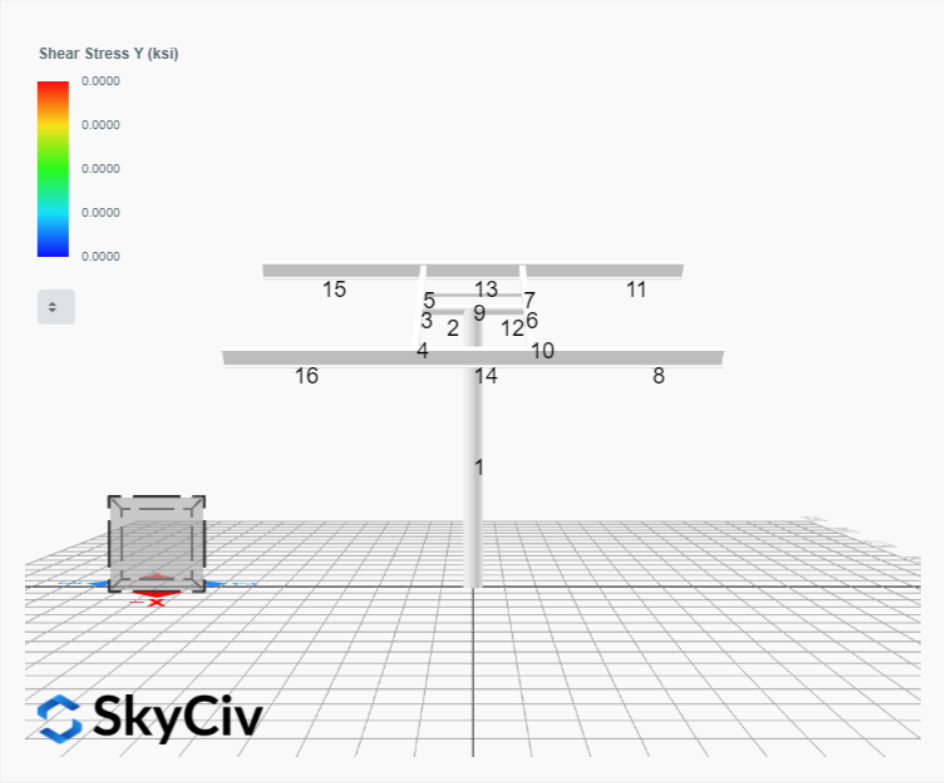

11
13
15
5
28
26
24
12
2
20
18
10
4
8
4
16
SkyCiv

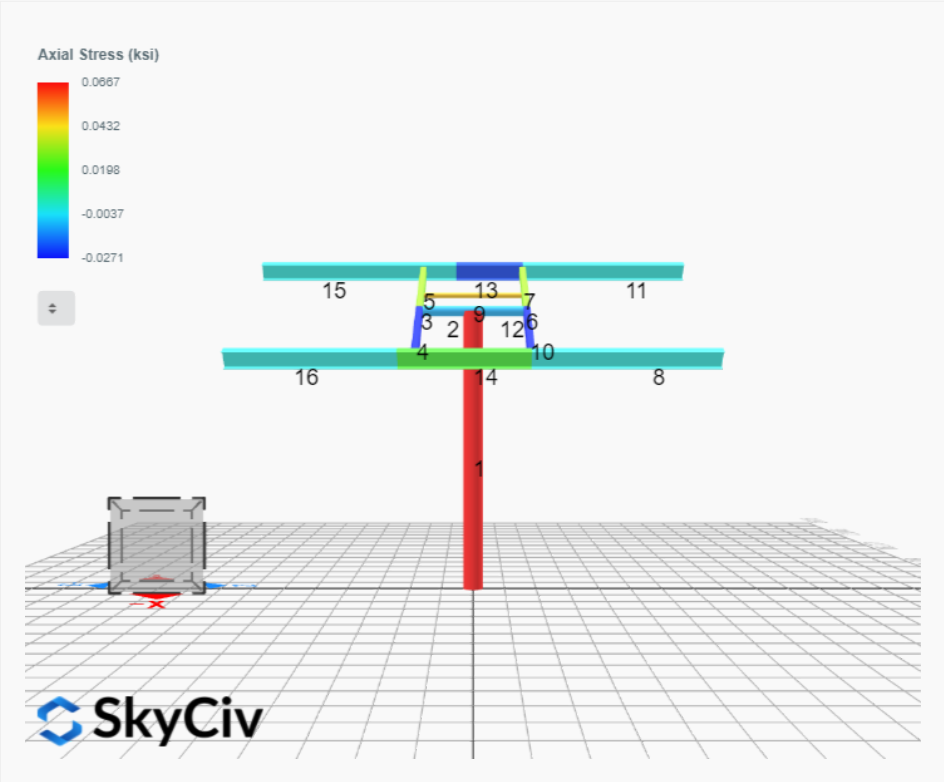
## FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
1.9674
0.9837
0.0000
-0.9837
-1.9674
15
13
11
5
7
3
2
9
12
6
4
10
16
14
8
1
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
13
11
5
7
3
2
9
12
6
4
10
16
14
8
1
SkyCiv


Axial Stress (ksi)
0.0667
0.0432
0.0198
-0.0037
-0.0271
15
13
11
5
7
3
2
9
12
6
4
10
16
14
8
1
SkyCiv

## Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

### ASD Load Combination Results

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 1. D | -0.0000 | 2.3434 | -0.0000 | 0.0000 | -0.0000 | 0.0274 |
| ULS: 2. D + L | -0.0000 | 2.3434 | -0.0000 | 0.0000 | -0.0000 | 0.0274 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 2.9033 | -0.0000 | 0.0000 | -0.0000 | 0.0278 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 2.3434 | -0.0000 | 0.0000 | -0.0000 | 0.0274 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 2.7634 | -0.0000 | 0.0000 | -0.0000 | 0.0277 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 2.3434 | -0.0000 | 0.0000 | -0.0000 | 0.0274 |
| ULS: 5b. D + 0.7E | -0.0000 | 2.3434 | -0.0000 | 0.0000 | -0.0000 | 0.0274 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 2.7634 | -0.0000 | 0.0000 | -0.0000 | 0.0277 |
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.4061 | -0.0000 | 0.0000 | -0.0000 | 0.0164 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.5820 | 6.8156 | -0.0000 | 0.0000 | -0.0000 | 27.1752 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.5820 | 6.8156 | -0.0000 | 0.0000 | -0.0000 | 27.1752 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.2131 | -1.4898 | -0.0000 | 0.0000 | -0.0000 | -22.4700 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 1.8443 | -0.8509 | -0.0000 | 0.0000 | -0.0000 | -27.8131 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.9365 | 6.1175 | -0.0000 | 0.0000 | -0.0000 | 20.3885 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.9365 | 6.1175 | -0.0000 | 0.0000 | -0.0000 | 20.3885 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6599 | -0.1116 | -0.0000 | 0.0000 | -0.0000 | -16.8454 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3832 | 0.3676 | -0.0000 | 0.0000 | -0.0000 | -20.8527 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.9365 | 5.6975 | -0.0000 | 0.0000 | -0.0000 | 20.3883 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.9365 | 5.6975 | -0.0000 | 0.0000 | -0.0000 | 20.3883 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6599 | -0.5315 | -0.0000 | 0.0000 | -0.0000 | -16.8456 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3832 | -0.0523 | -0.0000 | 0.0000 | -0.0000 | -20.8530 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.5820 | 5.8782 | -0.0000 | 0.0000 | -0.0000 | 27.1643 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.5820 | 5.8782 | -0.0000 | 0.0000 | -0.0000 | 27.1643 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.2131 | -2.4272 | -0.0000 | 0.0000 | -0.0000 | -22.4809 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 1.8443 | -1.7883 | -0.0000 | 0.0000 | -0.0000 | -27.8241 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 10.5456 |
| Shear X | -4.3033 |
| Shear Z | 0.0000 |
| Moment X | -0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 46.7881 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 6.8156 |
| Shear X | -2.5820 |
| Shear Z | -0.0000 |
| Moment X | 0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 27.8241 |

## Project Details

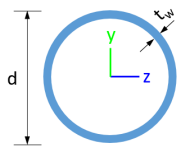
| | |
|---|---|
| Design Code: | AISC 360-16 LRFD |
| Provision: | LRFD |
| Country: | United States |
| User Name: | sales@mtsolar.us |
| Project Name: | G, CJ Anderson 8k upgrade |
| Unit System: | imperial |

## Design Input Information

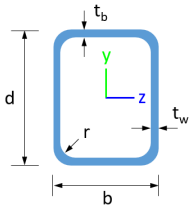
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

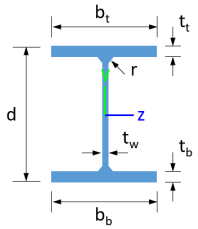
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | | |
| 9 | 8in Pipe Sch 40 | 8.63 | 0.32 | | | | | |




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




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

**Section Properties**

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

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

| Member Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 9 | 21.68 | 21.68 | 10.32 | - | 300 | 200 | 1 |
| 2 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.96,1.67,1.67,1.66,1.42,1.67,1.67,1.63,1.69,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.63 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 8 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.96,1.67,1.67,1.66,1.41,1.67,1.67,1.63,1.69,1.67,1.67,1.65,1.70,1.67,1.67,1.66,1.63 | 300 | 200 | 1 |
| 11 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.07,1.03,1.03,1.03,1.05,1.03,1.03,1.03,1.03 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.01,1.03,1.03,1.03,1.01,1.03,1.03,1.03,1.09,1.03,1.03,1.03,1.22,1.03,1.03,1.03,1.02 | 300 | 200 | 1 |
| 15 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 19 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |

## Member Design Capacity

| Member ID | $\Phi_tP_n$ (kip) | $\Phi_cP_n$ (kip) | $\Phi_bM_{zn}$ (k-ft) | $\Phi_bM_{yn}$ (k-ft) | $\Phi_vV_{yn}$ (kip) | $\Phi_vV_{zn}$ (kip) |
|---|---|---|---|---|---|---|
| 1 | 377.97 | 213.04 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 198.33 | 196.72 | 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 | 32.95 | 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 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 104.94 | 23.60 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 104.94 | 23.14 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 32.95 | 32.87 | 6.12 | 40.24 | 43.62 |

## 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 | 0.050 | 0.562 | 0.000 | 0.038 | 0.000 | 0.573 | #13 | 0.443 | Not Required | Pass |
| 2 | 0.001 | 0.408 | 0.193 | 0.086 | 0.036 | 0.602 | #13 | 0.035 | Not Required | Pass |
| 3 | 0.004 | 0.646 | 0.019 | 0.065 | 0.001 | 0.662 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.004 | 0.644 | 0.066 | 0.065 | 0.014 | 0.679 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.003 | 0.400 | 0.068 | 0.064 | 0.017 | 0.415 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.004 | 0.646 | 0.019 | 0.065 | 0.001 | 0.662 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.003 | 0.400 | 0.068 | 0.064 | 0.017 | 0.415 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.000 | 0.109 | 0.084 | 0.037 | 0.005 | 0.176 | #13 | Not Required | Not Required | Pass |
| 9 | 0.006 | 0.065 | 0.040 | 0.001 | 0.000 | 0.108 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.004 | 0.644 | 0.066 | 0.065 | 0.014 | 0.679 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.000 | 0.109 | 0.084 | 0.037 | 0.005 | 0.176 | #13 | Not Required | Not Required | Pass |
| 12 | 0.001 | 0.408 | 0.193 | 0.086 | 0.036 | 0.602 | #13 | 0.035 | Not Required | Pass |
| 13 | 0.003 | 0.297 | 0.157 | 0.051 | 0.007 | 0.409 | #13 | 0.190 | Not Required | Pass |
| 14 | 0.003 | 0.302 | 0.157 | 0.051 | 0.007 | 0.409 | #13 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.109 | 0.084 | 0.037 | 0.005 | 0.176 | #13 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.109 | 0.084 | 0.037 | 0.005 | 0.176 | #13 | Not Required | 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 |

| | |
|---|---|
| OK | Capacity is provided |
| NG | Capacity is not provided |

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

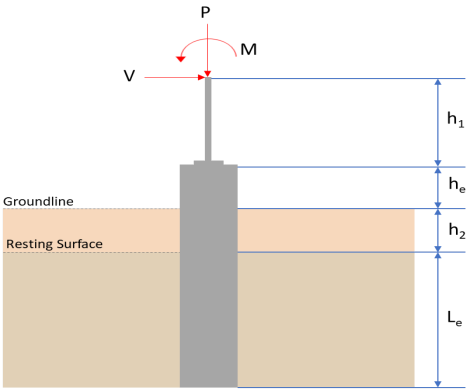
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 6.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.816 | 10.546 |
| $V_x$ (kip) | -2.582 | -4.303 |
| $V_z$ (kip) | 0.000 | 0.000 |
| $M_x$ (kipft) | 0.000 | 0.000 |
| $M_z$ (kipft) | 27.824 | 46.788 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.582\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.41115\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(27.824\ \text{kipft}) + ((-2.582\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.4306\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.9272\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$L_{e,z} = 0\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(5.9272\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 5.927\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.927\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.91185$$

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

**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

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

$$q = \frac{(6.816\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.426\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.426\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.213$$

Status: **PASS**
Ratio: **0.210**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.41115\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.4306\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.4306\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.41115\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.4306\ \text{kipft/ft})) + (4 \times (-0.41115\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4887\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.4306\ \text{kipft/ft})) + (3 \times (-0.41115\ \text{kip/ft}) \times (6.5\ \text{ft}))]^{\ 2}}{(6.5\ \text{ft})^2 \times [(3 \times (4.4306\ \text{kipft/ft})) + (2 \times (-0.41115\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.21039\ \text{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.4306\ \text{kipft/ft})) + ((-0.41115\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.87887\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.4887\ \text{ft})}{2}$$

$$p_a = 0.33665\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.21039\ \text{kip/ft}^2)}{(0.33665\ \text{kip/ft}^2)}$$

$$Ratio = 0.62495$$

Status: **PASS**
Ratio: **0.620**

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

$$p_s = R\ L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.5\ \text{ft})$$

$$p_s = 0.975\ \text{kip/ft}^2$$

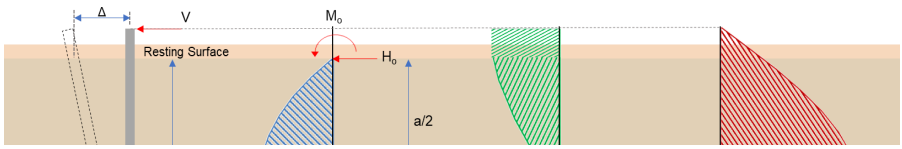
$Ratio$ - Lateral soil capacity

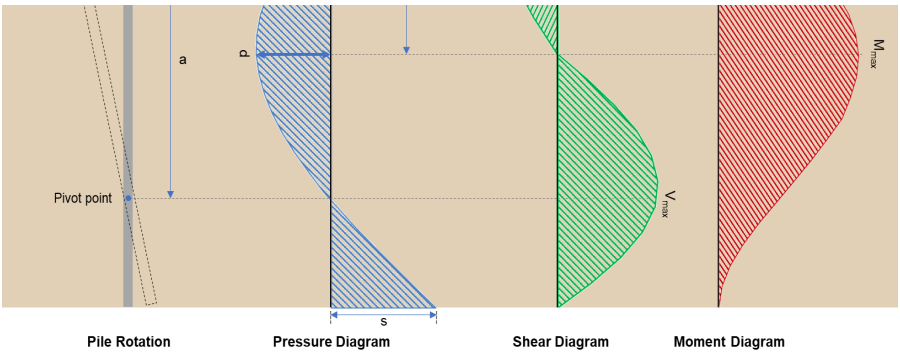
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.87887\ \text{kip/ft}^2)}{(0.975\ \text{kip/ft}^2)}$$

$$Ratio = 0.9014$$

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






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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.303\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.68519\text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(46.788\text{ kipft}) + ((-4.303\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 7.4503\text{ kipft/ft}$$

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

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

$$E = \frac{(7.4503\text{ kipft/ft})}{(-0.68519\text{ kip/ft})}$$

$$E = 10.873\text{ ft}$$

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

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

$$a = \frac{(4 \times (7.4503\text{ kipft/ft}) \times (6.5\text{ ft})) + \left(3 \times (-0.68519\text{ kip/ft}) \times (6.5\text{ ft})^2\right)}{(6 \times (7.4503\text{ kipft/ft})) + (4 \times (-0.68519\text{ kip/ft}) \times (6.5\text{ ft}))}$$

$$a = 4.4877\text{ ft}$$

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

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

$$V_{max} = ((-0.68519\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.873\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.4877\text{ ft})}{(6.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.873\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.4877\text{ ft})}{(6.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 9.9203\text{ kip}$$

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

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

$$M_{max} = ((-0.68519\text{ kip/ft}) \times (48\text{ in}) \times (6.5\text{ ft})) \times \left[\left(\frac{(10.873\text{ ft})}{(6.5\text{ ft})} + \frac{(4.4877\text{ ft})}{2 \times (6.5\text{ ft})}\right) - \left[\left(\frac{4 \times (10.873\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.4877\text{ ft})}{2 \times (6.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.873\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.4877\text{ ft})}{2 \times (6.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 30.624 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.546 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.246 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.246 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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**

**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

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

$$Ratio = \frac{(10.546\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0039422$$

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

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

**Parameters:**

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

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - 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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.546\ \text{kip} \rightarrow 10546\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10546\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.89\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.89\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.89\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.89\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.01\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 9.9203\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.9203\ \text{kip})}{(111.01\ \text{kip})}$$

$$Ratio = 0.089364$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

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:**

$M_{max} = 30.624 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(30.624 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.12269$$

Status: **PASS**
Ratio: **0.120**