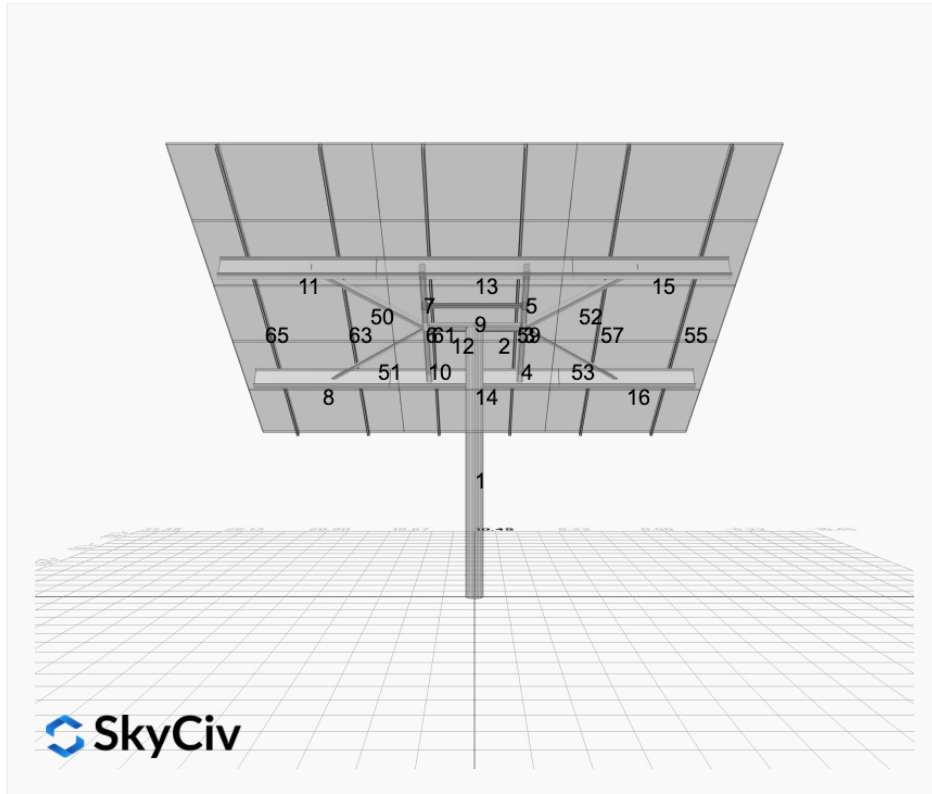


**Project Name:** Tiskus - Easthampton DE RE 33deg Struts - V1Jb  
**Location:** 94 West St, Easthampton, MA 01027, USA  
**Unique ID:** 1P-0-8TOP-XD-72-L-5Hx3W-STRUTS-B0A2  
**Dealer:** \_\_\_\_\_

**Date:** Wed May 14 2025  
**Number of Modules:** 15  
**Number of Poles:** 1  
**Date Sold:** \_\_\_\_\_



|                             |          |
|-----------------------------|----------|
| <b>Array Dimensions N/S</b> | 18.80 ft |
| <b>Array Dimensions E/W</b> | 20.90 ft |
| <b>Winter Tilt Angle</b>    | 33       |
| <b>Front Edge Clearance</b> | 6 ft     |

### MT Solar Bill of Materials (1P-0-8TOP-XD-72-L-5Hx3W-STRUTS-B0A2)

| Part                | Short Description     | BOM Qty |
|---------------------|-----------------------|---------|
| MTS-PC-8            | 8IN Pole Cap Assembly | 1       |
| MTS-HF-XD           | H-Frame Assembly-XD   | 1       |
| MTS-XD-Wing-72      | 72IN XD Wing          | 4       |
| MTS-CLAMP-ANGLE-4PK | Angle Clamp           | 3       |

### Rail Bill of Materials

| Part             | Qty |
|------------------|-----|
| Rails (226in)    | 6   |
| Rail Attachment  | 24  |
| Module Mid Clamp | 24  |
| Module End Clamp | 12  |
| Ground Lug       | 3   |

## Site Details:



**Site Address:** 94 West St, Easthampton, MA 01027, USA

### Array Specification

|                                    |                   |
|------------------------------------|-------------------|
| <b>Duty Classification:</b>        | XD                |
| <b>Module Width:</b>               | 44.61 in          |
| <b>Module Length:</b>              | 82.60in           |
| <b>Number of Rows:</b>             | 5                 |
| <b>Number of Columns:</b>          | 3                 |
| <b>Total Number of Modules:</b>    | 15                |
| <b>Winter Tilt Angle:</b>          | 33                |
| <b>Front Edge Clearance:</b>       | 6                 |
| <b>Total Array Height at Tilt:</b> | 16.24 ft          |
| <b>Total Frame Length:</b>         | 19.50 ft          |
| <b>Module Info/Notes:</b>          | SILFAB SIL-530 XM |
| <b>Array Dimensions N/S:</b>       | 18.80 ft          |
| <b>Array Dimensions E/W:</b>       | 20.90 ft          |
| <b>Rail Length:</b>                | 225.55 in         |
| <b>Rail Spacing:</b>               | 3.48 ft           |

### Support Specifications

|                                 |                 |
|---------------------------------|-----------------|
| <b>Pole Size:</b>               | 8in Pipe Sch 40 |
| <b>Pole Length above Grade:</b> | 11.12 ft        |
| <b>Number of Poles:</b>         | 1               |
| <b>Pole Spacing:</b>            | 0               |

### Foundation Specifications

|  |                      |
|--|----------------------|
| <b>Foundation Type:</b>                | Round                |
| <b>Foundation Dimensions:</b>          | Ø36 in               |
| <b>Foundation Depth (below grade):</b> | Pile 1: 30.00 ft     |
| <b>Foundation Volume:</b>              | 7.854 y <sup>3</sup> |

### Site Info

|                             |  |
|-----------------------------|--|
| <b>Risk Category:</b>       | I                                      |
| <b>Exposure:</b>            | B                                      |
| <b>Soil Classification:</b> | sand                                   |
| <b>Site Location:</b>       | 94 West St, Easthampton, MA 01027, USA |
| <b>Wind Speed:</b>          | 114 mph                                |
| <b>Snow Load:</b>           | 40 psf                                 |

### **Design Disclaimer**

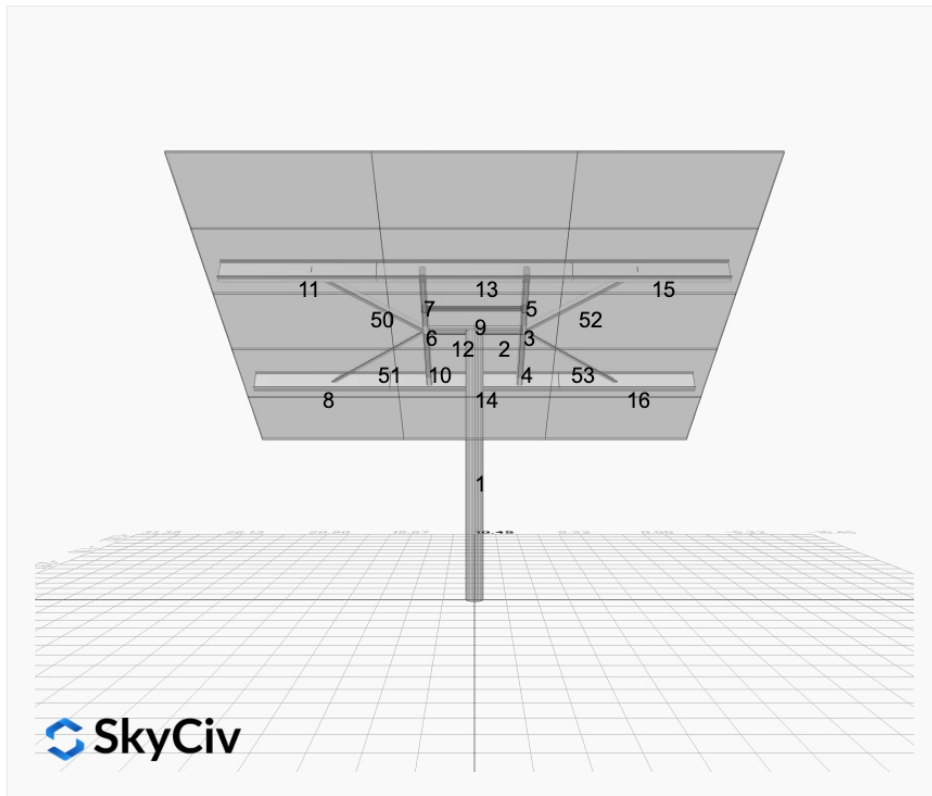
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

## AutoDesigner Input

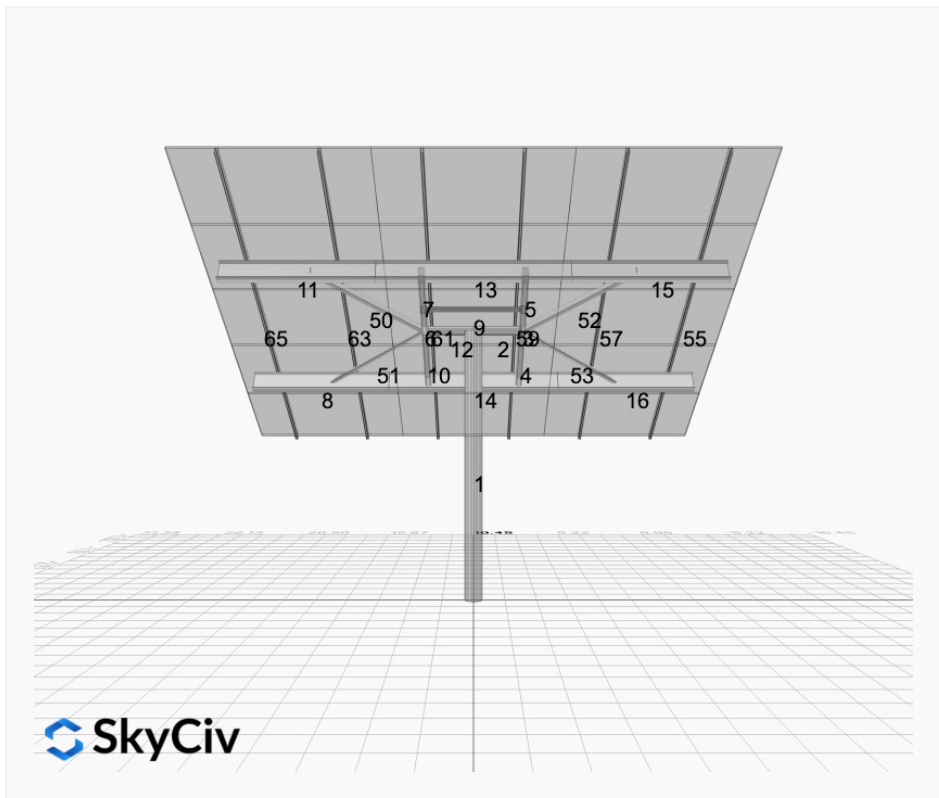
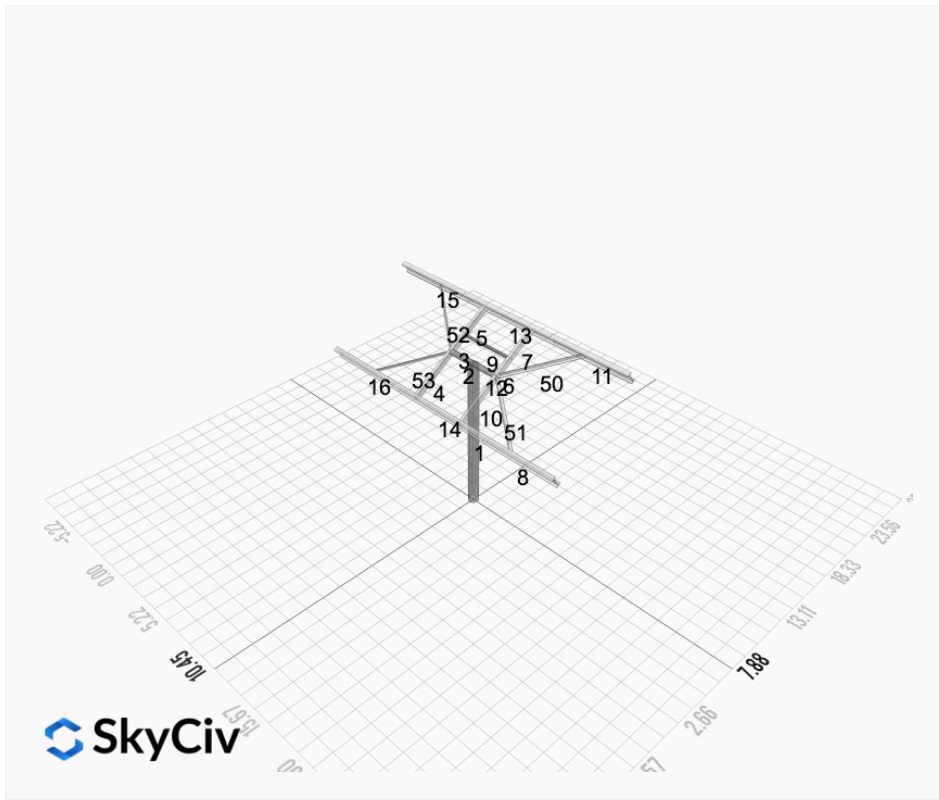
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## Design Notes:

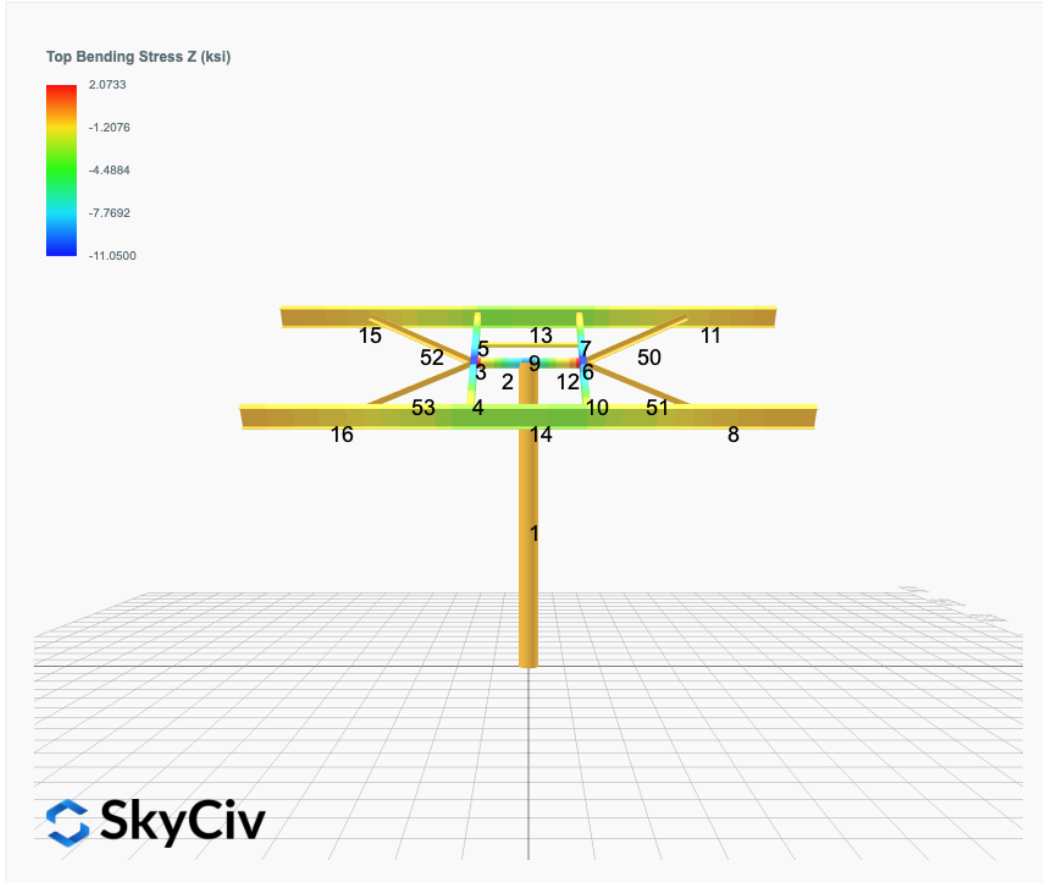
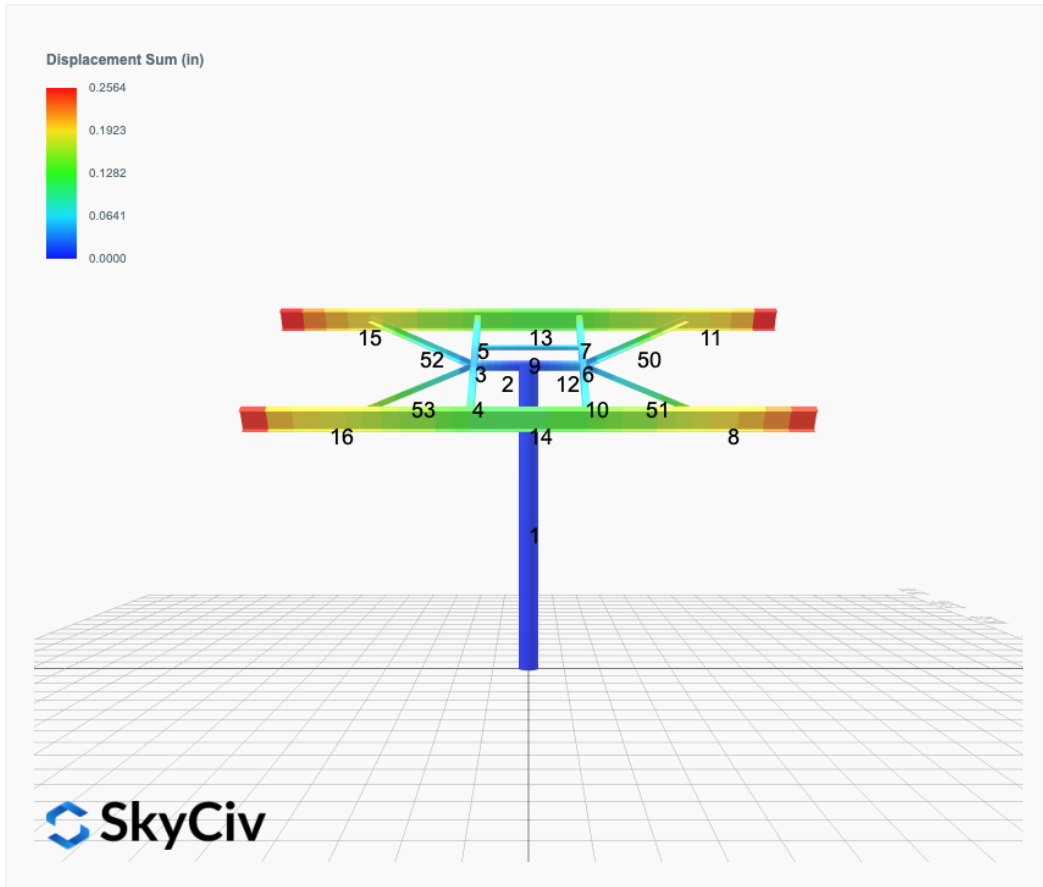
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



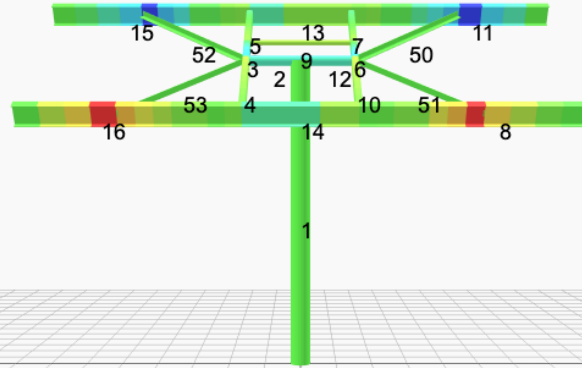
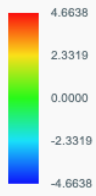




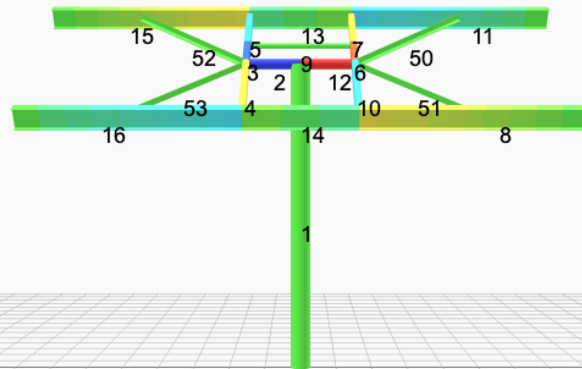
# FEM Results (Envelope Worst Case for each member)



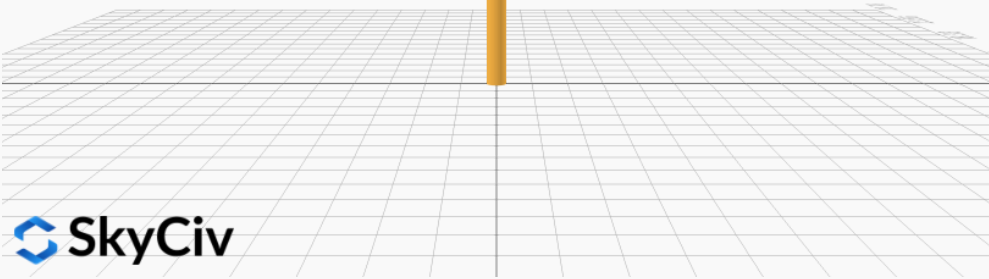
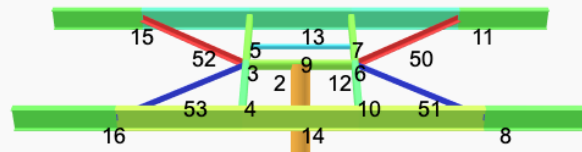
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



## 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  | 2.8803  | 0.0000 | -0.0000 | -0.0000 | 0.0315   |
| ULS: 2. D + L   | 0.0000  | 2.8803  | 0.0000 | -0.0000 | -0.0000 | 0.0315   |
| ULS: 3. D + (S or Lr or R)  | 0.0000  | 7.8829  | 0.0000 | -0.0000 | -0.0000 | 0.0642   |
| ULS: 3. D + (S or Lr or R)  | 0.0000  | 2.8803  | 0.0000 | -0.0000 | -0.0000 | 0.0315   |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0000  | 6.6323  | 0.0000 | -0.0000 | -0.0000 | 0.0560   |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0000  | 2.8803  | 0.0000 | -0.0000 | -0.0000 | 0.0315   |
| ULS: 5b. D + 0.7E   | 0.0000  | 2.8803  | 0.0000 | -0.0000 | -0.0000 | 0.0315   |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S   | 0.0000  | 6.6323  | 0.0000 | -0.0000 | -0.0000 | 0.0560   |
| ULS: 8. 0.6D + 0.7E   | 0.0000  | 1.7282  | 0.0000 | -0.0000 | -0.0000 | 0.0189   |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -3.7353 | 8.6321  | 0.0000 | -0.0000 | -0.0000 | 42.9762  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | -3.7353 | 8.6321  | 0.0000 | -0.0000 | -0.0000 | 42.9762  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 3.1715  | -2.0033 | 0.0000 | -0.0000 | -0.0000 | -34.4418 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 2.6429  | -1.1894 | 0.0000 | -0.0000 | -0.0000 | -40.1227 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8014 | 10.9461 | 0.0000 | -0.0000 | -0.0000 | 32.2646  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.8014 | 10.9461 | 0.0000 | -0.0000 | -0.0000 | 32.2646  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 2.3786  | 2.9696  | 0.0000 | -0.0000 | -0.0000 | -25.7990 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.9822  | 3.5800  | 0.0000 | -0.0000 | -0.0000 | -30.0597 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8014 | 7.1941  | 0.0000 | -0.0000 | -0.0000 | 32.2400  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.8014 | 7.1941  | 0.0000 | -0.0000 | -0.0000 | 32.2400  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 2.3786  | -0.7824 | 0.0000 | -0.0000 | -0.0000 | -25.8235 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.9822  | -0.1720 | 0.0000 | -0.0000 | -0.0000 | -30.0842 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -3.7353 | 7.4800  | 0.0000 | -0.0000 | -0.0000 | 42.9636  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -3.7353 | 7.4800  | 0.0000 | -0.0000 | -0.0000 | 42.9636  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 3.1715  | -3.1554 | 0.0000 | -0.0000 | -0.0000 | -34.4544 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 2.6429  | -2.3415 | 0.0000 | -0.0000 | -0.0000 | -40.1353 |

### Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundation Module.

Note: Worst case values are assumed as downforce wind load cases.

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 16.2537             |
| Shear X          | -6.2254             |
| Shear Z          | 0.0000              |
| Moment X         | 0.0012              |
| Moment Y (Twist) | 0.0017              |
| Moment Z         | 73.0283             |

### 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            | 10.9461             |
| Shear X          | -3.7353             |
| Shear Z          | 0.0000              |
| Moment X         | -0.0000             |
| Moment Y (Twist) | 0.0000              |
| Moment Z         | 42.9762             |

## Project Details

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

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

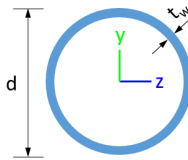


## Design Input Information

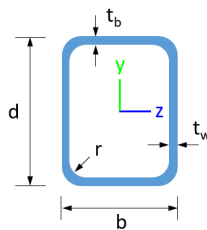
| Design Factors |          |          |          |
|----------------|----------|----------|----------|
| $\Phi_t$       | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9            | 0.9      | 0.9      | 0.9      |

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

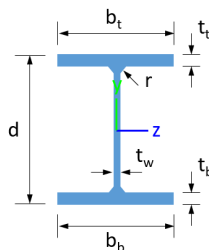
### Section Dimensions



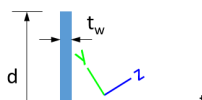
| ID | Name             | d (in) | $t_w$ (in) |  |  |  |  |
|----|------------------|--------|------------|--|--|--|--|
| 3  | 2in Pipe Sch 120 | 2.38   | 0.25       |  |  |  |  |
| 6  | 4in Pipe Sch 120 | 4.50   | 0.44       |  |  |  |  |
| 9  | 8in Pipe Sch 40  | 8.63   | 0.32       |  |  |  |  |



| ID | Name       | d (in) | b (in) | $t_w$ (in) | $t_b$ (in) | r (in) |  |
|----|------------|--------|--------|------------|------------|--------|--|
| 17 | HSS5x3x1/4 | 5.00   | 3.00   | 0.23       | 0.23       | 0.23   |  |



| ID | Name   | d (in) | $t_w$ (in) | $b_t$ (in) | $b_b$ (in) | $t_t$ (in) | $t_b$ (in) | r (in) |
|----|--------|--------|------------|------------|------------|------------|------------|--------|
| 20 | W10x12 | 9.87   | 0.19       | 3.96       | 3.96       | 0.21       | 0.21       | 0.30   |





Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|-----------|--------------------|--------------------|------------------------|------------------------|-----------------------|-----------------------|
| 1         | 377.97             | 194.36             | 83.29                  | 83.29                  | 113.39                | 113.39                |
| 2         | 251.01             | 248.88             | 27.16                  | 27.16                  | 75.30                 | 75.30                 |
| 3         | 151.65             | 150.70             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 4         | 151.65             | 145.15             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 5         | 151.65             | 149.10             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 6         | 151.65             | 150.70             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 7         | 151.65             | 149.10             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 8         | 159.30             | 86.08              | 46.90                  | 6.46                   | 56.26                 | 44.91                 |
| 9         | 75.10              | 66.32              | 4.25                   | 4.25                   | 22.53                 | 22.53                 |
| 10        | 151.65             | 145.15             | 20.17                  | 14.14                  | 54.12                 | 28.95                 |
| 11        | 159.30             | 86.08              | 46.90                  | 6.46                   | 56.26                 | 44.91                 |
| 12        | 251.01             | 248.88             | 27.16                  | 27.16                  | 75.30                 | 75.30                 |
| 13        | 159.30             | 97.43              | 31.17                  | 6.46                   | 56.26                 | 44.91                 |
| 14        | 159.30             | 97.43              | 30.95                  | 6.46                   | 56.26                 | 44.91                 |
| 15        | 159.30             | 86.08              | 46.90                  | 6.46                   | 56.26                 | 44.91                 |
| 16        | 159.30             | 86.08              | 46.90                  | 6.46                   | 56.26                 | 44.91                 |
| 50        | 41.27              | 8.45               | 1.63                   | 0.76                   | 15.23                 | 10.15                 |
| 51        | 41.27              | 8.45               | 1.63                   | 0.76                   | 15.23                 | 10.15                 |
| 52        | 41.27              | 8.45               | 1.63                   | 0.76                   | 15.23                 | 10.15                 |
| 53        | 41.27              | 8.45               | 1.63                   | 0.76                   | 15.23                 | 10.15                 |

Design Ratio

| Member ID | P     | M <sub>z</sub> | M <sub>y</sub> | V <sub>y</sub> | V <sub>z</sub> | (P,M <sub>z</sub> ,M <sub>y</sub> ) | Worst LC | KL/r  | $\delta$     | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|-------|--------------|--------|
| 1         | 0.084 | 0.877          | 0.000          | 0.055          | 0.000          | 0.917                               | #13      | 0.477 | Not Required | Pass   |
| 2         | 0.005 | 0.492          | 0.228          | 0.105          | 0.041          | 0.713                               | #13      | 0.054 | Not Required | Pass   |
| 3         | 0.003 | 0.749          | 0.111          | 0.075          | 0.046          | 0.810                               | #21      | 0.046 | Not Required | Pass   |
| 4         | 0.003 | 0.735          | 0.039          | 0.073          | 0.005          | 0.756                               | #13      | 0.082 | Not Required | Pass   |
| 5         | 0.003 | 0.465          | 0.022          | 0.074          | 0.008          | 0.476                               | #13      | 0.076 | Not Required | Pass   |
| 6         | 0.003 | 0.749          | 0.111          | 0.075          | 0.046          | 0.810                               | #21      | 0.046 | Not Required | Pass   |
| 7         | 0.003 | 0.465          | 0.022          | 0.074          | 0.008          | 0.476                               | #13      | 0.076 | Not Required | Pass   |
| 8         | 0.014 | 0.155          | 0.141          | 0.043          | 0.012          | 0.197                               | #21      | 0.459 | Not Required | Pass   |
| 9         | 0.021 | 0.074          | 0.049          | 0.001          | 0.000          | 0.129                               | #13      | 0.137 | Not Required | Pass   |
| 10        | 0.003 | 0.735          | 0.039          | 0.073          | 0.005          | 0.756                               | #13      | 0.082 | Not Required | Pass   |
| 11        | 0.008 | 0.158          | 0.141          | 0.044          | 0.012          | 0.194                               | #21      | 0.306 | Not Required | Pass   |
| 12        | 0.005 | 0.492          | 0.228          | 0.105          | 0.041          | 0.713                               | #13      | 0.054 | Not Required | Pass   |
| 13        | 0.008 | 0.414          | 0.028          | 0.057          | 0.007          | 0.429                               | #13      | 0.204 | Not Required | Pass   |
| 14        | 0.014 | 0.412          | 0.025          | 0.056          | 0.007          | 0.424                               | #13      | 0.306 | Not Required | Pass   |
| 15        | 0.008 | 0.158          | 0.141          | 0.044          | 0.012          | 0.194                               | #21      | 0.306 | Not Required | Pass   |
| 16        | 0.014 | 0.155          | 0.141          | 0.043          | 0.012          | 0.197                               | #21      | 0.306 | Not Required | Pass   |
| 50        | 0.192 | 0.010          | 0.001          | 0.002          | 0.001          | 0.201                               | #21      | 0.783 | Not Required | Pass   |
| 51        | 0.038 | 0.006          | 0.016          | 0.002          | 0.002          | 0.056                               | #21      | 0.522 | Not Required | Pass   |
| 52        | 0.192 | 0.010          | 0.001          | 0.002          | 0.001          | 0.201                               | #24      | 0.783 | Not Required | Pass   |
| 53        | 0.038 | 0.006          | 0.016          | 0.002          | 0.002          | 0.056                               | #24      | 0.522 | 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/compression)              |
| $M_n$           | 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               |
| $\delta$        | Design ratio in case of member deflection                 |
| OK              | Capacity is provided                                      |
| NG              | Capacity is not provided                                  |

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

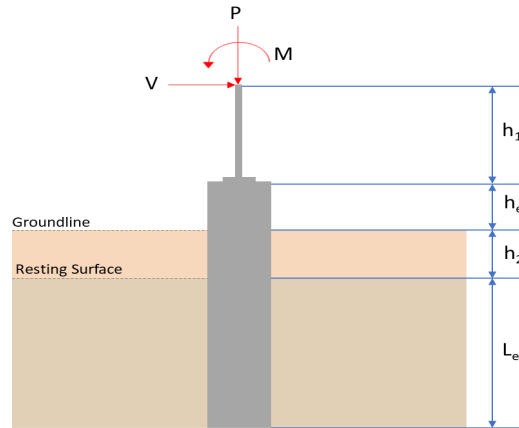
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: round

$D = 36$  in - Pile diameter

$L = 30$  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)      | 10.946 | 16.254 |
| $V_x$ (kip)    | -3.735 | -6.225 |
| $V_z$ (kip)    | 0.000  | 0.000  |
| $M_x$ (kipft)  | 0.000  | 0.001  |
| $M_z$ (kipft)  | 42.976 | 73.028 |

### 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,

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

$$H_o = \frac{(-3.735 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.245 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(42.976 \text{ kipft}) + ((-3.735 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.325 \text{ kipft/ft}$$

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:

$L_{e,x} = 9.0414 \text{ ft}$  - 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,

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

$$L_{e,req} = \text{MAX}[(9.0414 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 9.041 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (30 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 30 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(9.041 \text{ ft})}{(30 \text{ ft})}$$

$$\text{Ratio} = 0.30137$$

Status: **PASS**  
Ratio: **0.300**

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

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

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(10.946 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.5485 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.5485 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.77427$$

Status: **PASS**  
Ratio: **0.770**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(30 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 10$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -1.245 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 14.325 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (14.325 \text{ kipft/ft}) \times (30 \text{ ft})) + (3 \times (-1.245 \text{ kip/ft}) \times (30 \text{ ft})^2)}{(6 \times (14.325 \text{ kipft/ft})) + (4 \times (-1.245 \text{ kip/ft}) \times (30 \text{ ft}))}$$

$$a = 21.587 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (14.325 \text{ kipft/ft})) + (3 \times (-1.245 \text{ kip/ft}) \times (30 \text{ ft}))]^2}{(30 \text{ ft})^2 \times [(3 \times (14.325 \text{ kipft/ft})) + (2 \times (-1.245 \text{ kip/ft}) \times (30 \text{ ft}))]}$$

$$p = -0.12367 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (14.325 \text{ kipft/ft})) + ((-1.245 \text{ kip/ft}) \times (30 \text{ ft}))]}{(30 \text{ ft})^2}$$

$$s = -0.091101 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(21.587 \text{ ft})}{2}$$

$$p_a = 1.619 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.12367 \text{ kip/ft}^2)}{(1.619 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.076385$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (30 \text{ ft})$$

$$p_s = 4.5 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

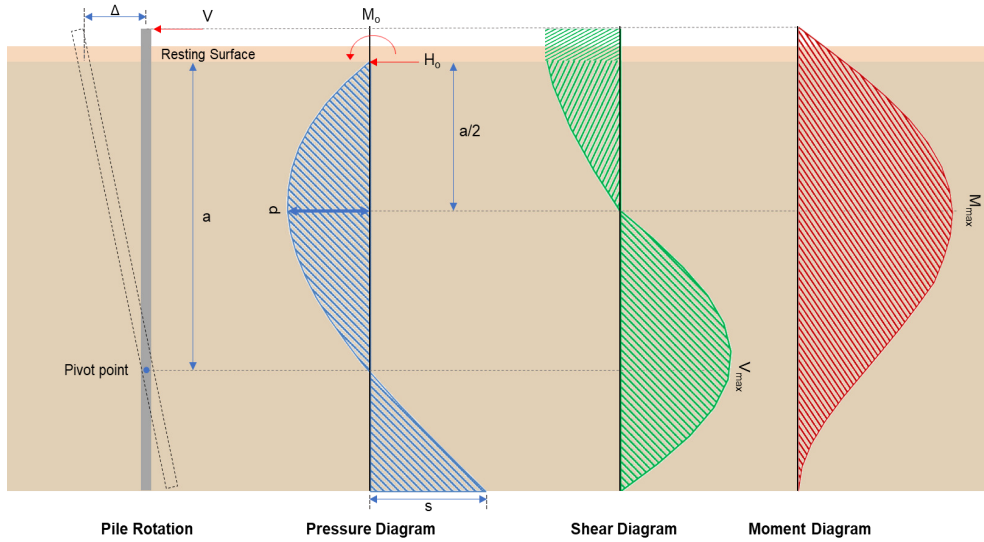
$$(-0.091101 \text{ kip/ft}^2)$$

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

$$Ratio = \frac{-0.020245}{(4.5 \text{ kip/ft}^2)}$$

$$Ratio = -0.020245$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-6.225 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -2.075 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(73.028 \text{ kipft}) + ((-6.225 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 24.343 \text{ kipft/ft}$$

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

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

$$E = \frac{(24.343 \text{ kipft/ft})}{(-2.075 \text{ kip/ft})}$$

$$E = 11.731 \text{ ft}$$

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

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

$$a = \frac{(4 \times (24.343 \text{ kipft/ft}) \times (30 \text{ ft})) + (3 \times (-2.075 \text{ kip/ft}) \times (30 \text{ ft})^2)}{(6 \times (24.343 \text{ kipft/ft})) + (4 \times (-2.075 \text{ kip/ft}) \times (30 \text{ ft}))}$$

$$a = 21.576 \text{ ft}$$

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

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

$$V_{max} = ((-2.075 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (11.731 \text{ ft})}{(30 \text{ ft})} + 3 \right) \times \left( \frac{(21.576 \text{ ft})}{(30 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (11.731 \text{ ft})}{(30 \text{ ft})} + 2 \right) \times \left( \frac{(21.576 \text{ ft})}{(30 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.4707 \text{ kip}$$

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

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

$$M_{max} = ((-2.075 \text{ kip/ft}) \times (36 \text{ in}) \times (30 \text{ ft})) \times \left[ \left( \frac{(11.731 \text{ ft})}{(30 \text{ ft})} + \frac{(21.576 \text{ ft})}{2 \times (30 \text{ ft})} \right) - \left[ \left( \frac{4 \times (11.731 \text{ ft})}{(30 \text{ ft})} + 3 \right) \times \left( \frac{(21.576 \text{ ft})}{2 \times (30 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (11.731 \text{ ft})}{(30 \text{ ft})} + 2 \right) \times \left( \frac{(21.576 \text{ ft})}{2 \times (30 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 110.46 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.001 \text{ kipft}) + ((0 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.00033333 \text{ kipft/ft}$$

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

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

$$a = \frac{(4 \times (0.00033333 \text{ kipft/ft}) \times (30 \text{ ft})) + (3 \times (0 \text{ kip/ft}) \times (30 \text{ ft})^2)}{(6 \times (0.00033333 \text{ kipft/ft})) + (4 \times (0 \text{ kip/ft}) \times (30 \text{ ft}))}$$

$$a = 20 \text{ ft}$$

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

$$V_{max} = 12 \left( \frac{M_o b}{L_e} \right) \left( \frac{a}{L_e} - 1 \right) \left( \frac{a}{L_e} \right)^2$$

$$V_{max} = 12 \times \left( \frac{(0.00033333 \text{ kipft/ft}) \times (36 \text{ in})}{(30 \text{ ft})} \right) \times \left( \frac{(20 \text{ ft})}{(30 \text{ ft})} - 1 \right) \times \left( \frac{(20 \text{ ft})}{(30 \text{ ft})} \right)^2$$

$$V_{max} = 0.000059259 \text{ kip}$$

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

$$M_{max} = (M_o b) \left[ 1 - \left( 4 \frac{a}{2 L_e} \right)^3 + \left( 3 \frac{a}{2 L_e} \right)^4 \right]$$

$$M_{max} = ((0.00033333 \text{ kipft/ft}) \times (36 \text{ in})) \times \left[ 1 - \left( 4 \times \frac{(20 \text{ ft})}{2 \times (30 \text{ ft})} \right)^3 + \left( 3 \times \frac{(20 \text{ ft})}{2 \times (30 \text{ ft})} \right)^4 \right]$$

$$M_{max} = 0.00088889 \text{ kipft}$$

### 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,

$\alpha = 0.85$  - Alpha factor for axial strength,

$A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

Table 22.4.2.1

22.4.2.2, 10.6.1.1

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

$$A_{st,required} = Min \left[ \frac{\frac{(16.254 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.865 \text{ in}^2$$

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

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

$$A_{min} = Max [(-36.865 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

Ratio - Capacity

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

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

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

Main reinforcement: **6 - #5 (0.625 in)**

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

22.4.2.2  $\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$Ratio = \frac{(16.254 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.012963$$

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

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

#### Parameters:

22.5.2.2  $b_w = 36$  in - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

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

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

22.5.5.1.3  $\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5$  ksi  $\rightarrow$  2500 psi,  $P = 16.254$  kip  $\rightarrow$  16254 lbf,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(16254 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.197 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5$  ksi  $\rightarrow$  2500 psi,  
 $V_{c,b}$  - Shear strength of concrete (b)

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

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

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

$V_c$  - Governing shear strength of concrete

$$V_c = MIN [V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = MIN [(186.09 \text{ kip}), (77.197 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 77.197 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5$  ksi  $\rightarrow$  2500 psi,  
 $V_{s,a}$  - Shear strength of steel (a)

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((77.197 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.989 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 8.4707 \text{ kip}$  - Maximum shear force in the x-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(8.4707 \text{ kip})}{(74.989 \text{ kip})}$$

$$\text{Ratio} = 0.11296$$

Status: **PASS**  
Ratio: **0.110**

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - Concrete modification factor (Normal concrete),

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

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

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

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

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

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

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

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

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

**Considering x-direction:**

$M_{max} = 110.46 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(110.46 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$\text{Ratio} = 1.7808$$

Status: **FAIL**  
Ratio: **1.780**

**Considering z-direction:**

$M_{max} = 0.00088889 \text{ kipft}$  - Maximum moment in the z-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(0.00088889 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$\text{Ratio} = 0.000014331$$

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