

**Project Name:** MTSOLAR\_0AC09DHIHG47F      **Date:** Tue Jun 17 2025  
**Location:** 15034 Melrose St, Overland Park, KS 66221, USA      **Number of Modules:** 36  
**Unique ID:** 3P-19.75-6TOP-HD-24-L-4Hx9W-H7LD      **Number of Poles:** 3  
**Dealer:** \_\_\_\_\_      **Date Sold:** \_\_\_\_\_



|                             |          |
|-----------------------------|----------|
| <b>Array Dimensions N/S</b> | 15.03 ft |
| <b>Array Dimensions E/W</b> | 51.60 ft |
| <b>Winter Tilt Angle</b>    | 30       |
| <b>Front Edge Clearance</b> | 1 ft     |

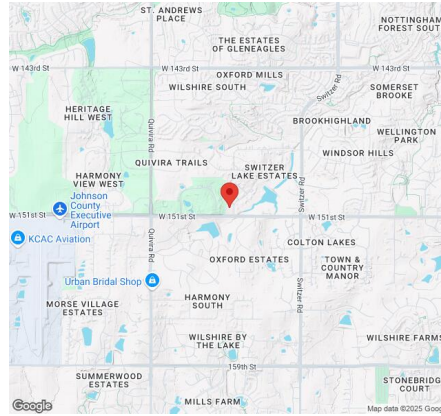
**MT Solar Bill of Materials (3P-19.75-6TOP-HD-24-L-4Hx9W-H7LD)**

| Part               | Short Description     | BOM Qty |
|--------------------|-----------------------|---------|
| MTS-PC-6           | 6IN Pole Cap Assembly | 3       |
| MTS-HF-HD          | H-Frame Assembly-HD   | 3       |
| MTS-HD-Wing-24     | 24IN HD Wing          | 4       |
| MTS-HD-Splice-90   | 90IN HD Splice        | 4       |
| MTS-HD-Splice-57   | 57IN HD Splice        | 4       |
| MTS-CLAMP-HOOK-4PK | Hook Clamp            | 9       |

**Rail Bill of Materials**

| Part             | Qty |
|------------------|-----|
| Rails (180in)    | 18  |
| Rail Attachment  | 36  |
| Module Mid Clamp | 54  |
| Module End Clamp | 36  |
| Ground Lug       | 9   |

## Site Details:



**Site Address:** 15034 Melrose St, Overland Park, KS 66221, USA

### Array Specification

|                                    |           |
|------------------------------------|-----------|
| <b>Duty Classification:</b>        | HD        |
| <b>Module Width:</b>               | 44.60 in  |
| <b>Module Length:</b>              | 67.80in   |
| <b>Number of Rows:</b>             | 4         |
| <b>Number of Columns:</b>          | 9         |
| <b>Total Number of Modules:</b>    | 36        |
| <b>Winter Tilt Angle:</b>          | 30        |
| <b>Front Edge Clearance:</b>       | 1         |
| <b>Total Array Height at Tilt:</b> | 8.52 ft   |
| <b>Total Frame Length:</b>         | 51.00 ft  |
| <b>Module Info/Notes:</b>          |           |
| <b>Array Dimensions N/S:</b>       | 15.03 ft  |
| <b>Array Dimensions E/W:</b>       | 51.60 ft  |
| <b>Rail Length:</b>                | 180.40 in |
| <b>Rail Spacing:</b>               | 2.87 ft   |

### Support Specifications

|                                 |                 |
|---------------------------------|-----------------|
| <b>Pole Size:</b>               | 6in Pipe Sch 40 |
| <b>Pole Length above Grade:</b> | 4.76 ft         |
| <b>Number of Poles:</b>         | 3               |
| <b>Pole Spacing:</b>            | 19.75 ft        |

### Foundation Specifications

|  |   |
|--|---|
| <b>Foundation Type:</b>                | Round   |
| <b>Foundation Dimensions:</b>          | Ø36 in  |
| <b>Foundation Depth (below grade):</b> | Pile 1: 7.25 ft<br>Pile 2: 7.50 ft<br>Pile 3: 7.25 ft |
| <b>Foundation Volume:</b>              | 5.760 y <sup>3</sup>                                  |

### Site Info

|                             |  |
|-----------------------------|--|
| <b>Risk Category:</b>       | I  |
| <b>Exposure:</b>            | C  |
| <b>Soil Classification:</b> | sand   |
| <b>Site Location:</b>       | 15034 Melrose St, Overland Park, KS 66221, USA |
| <b>Wind Speed:</b>          | 104 mph  |
| <b>Snow Load:</b>           | 20 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.

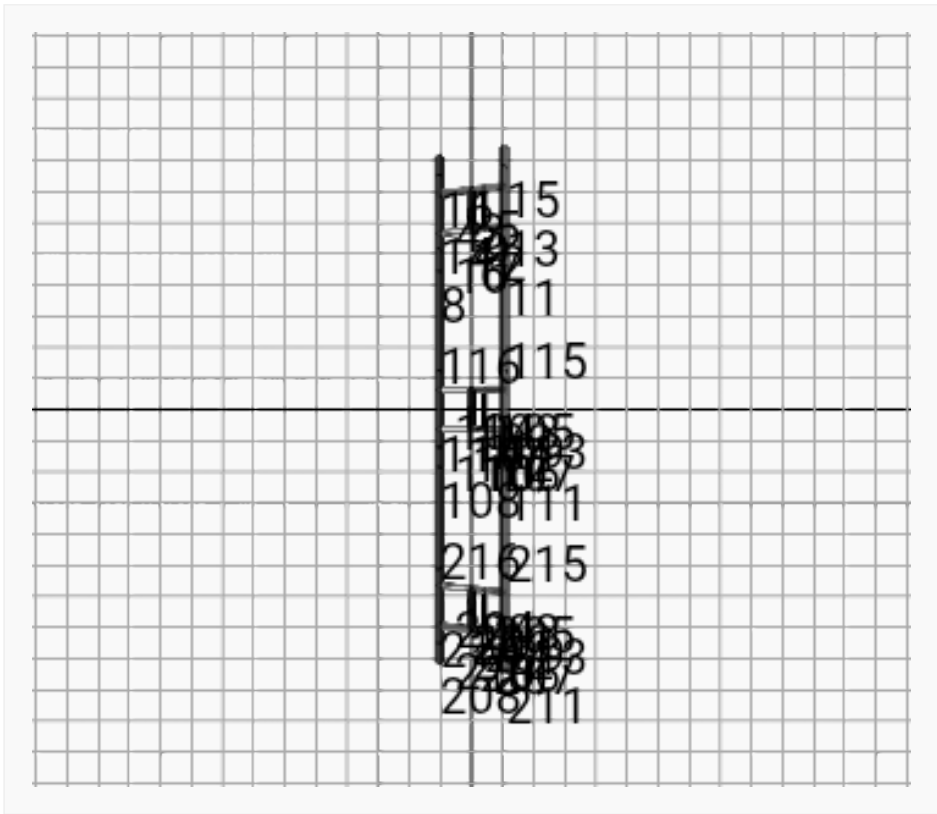
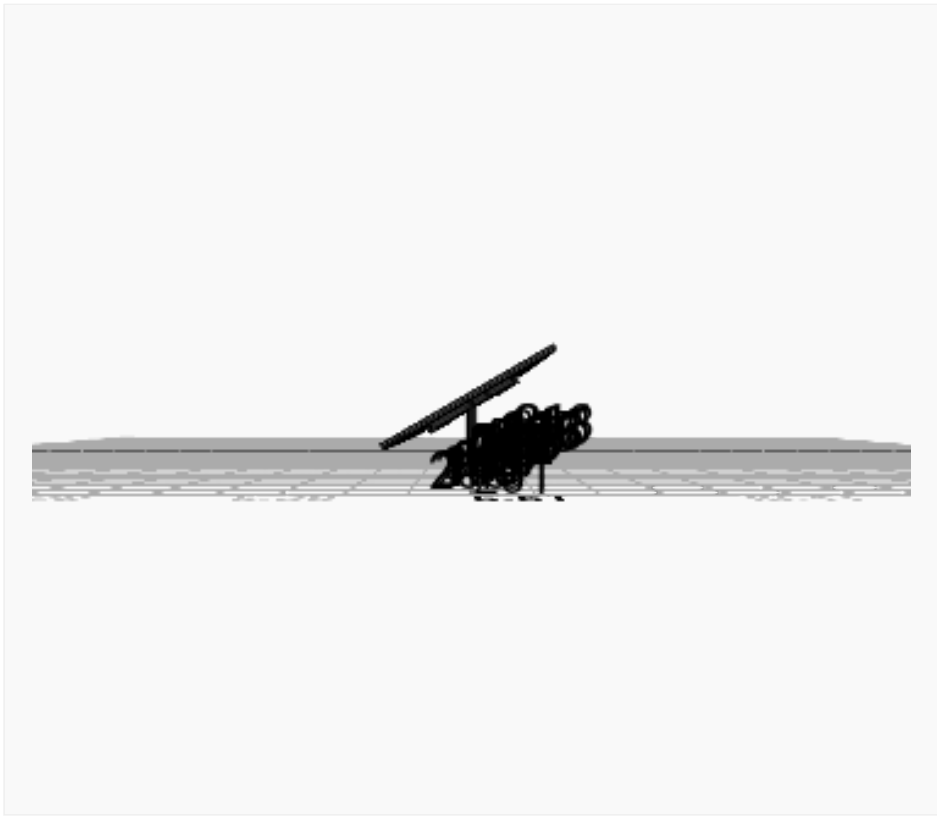
## AutoDesigner Input

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## Design Notes:

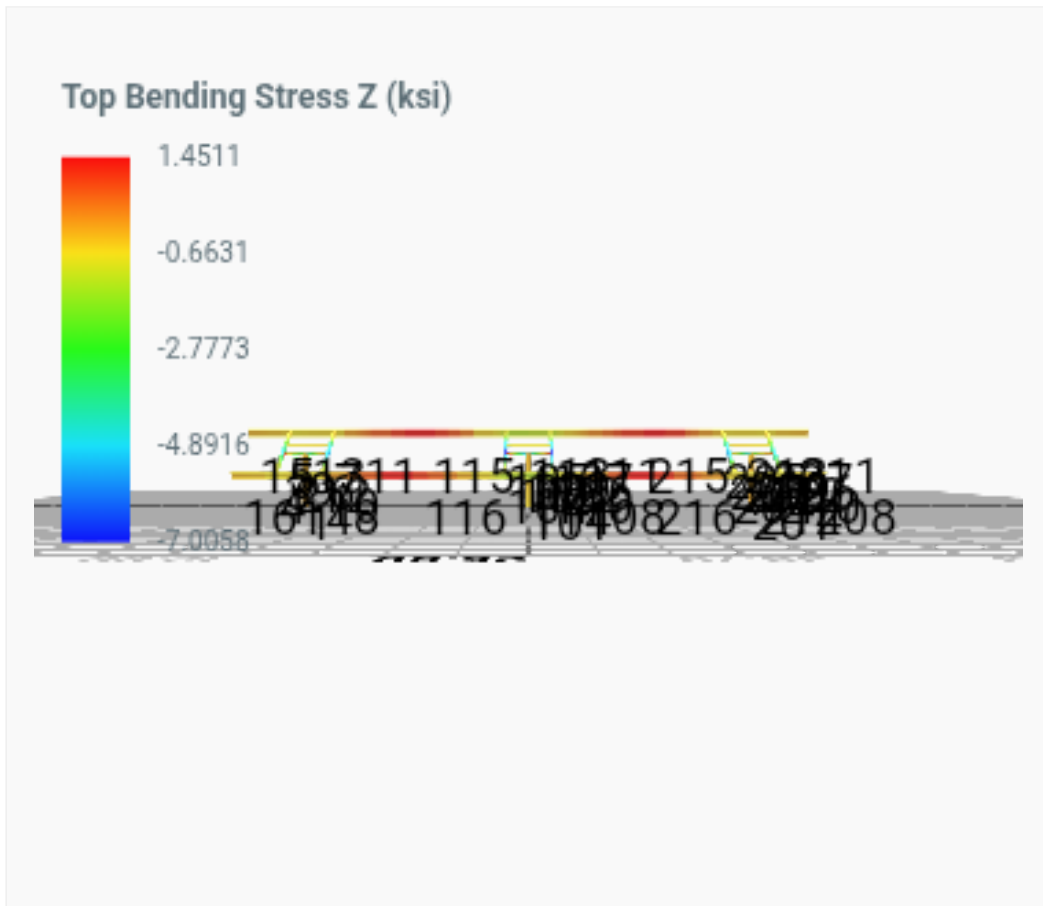
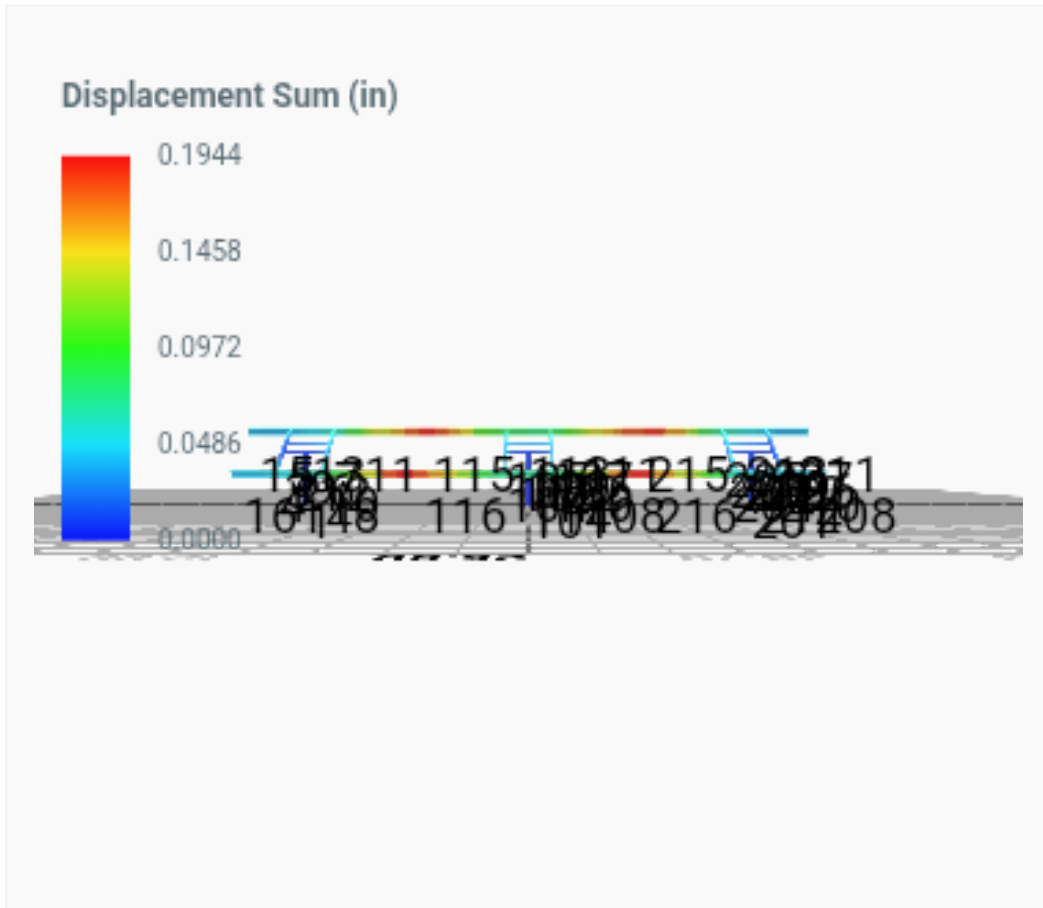
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



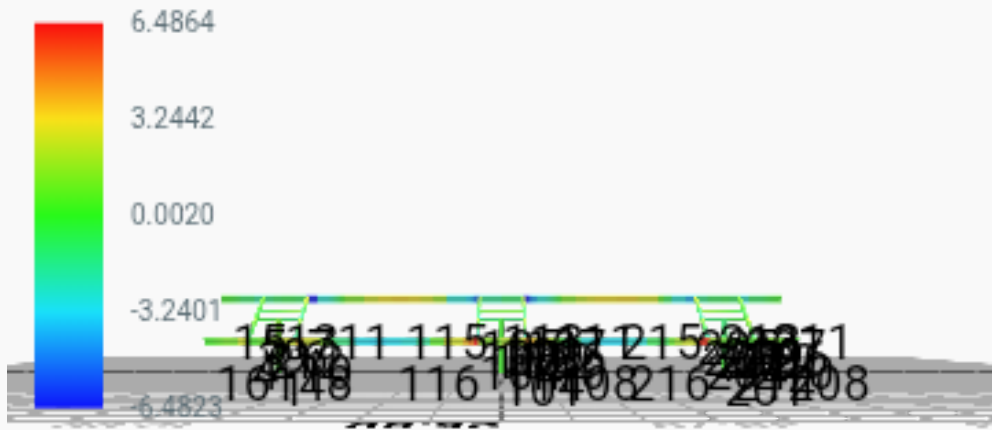




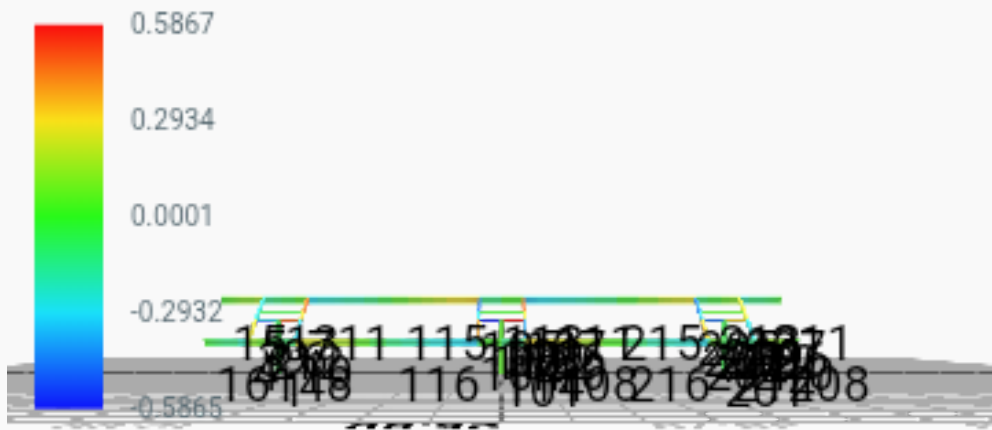
# FEM Results (Envelope Worst Case for each member)

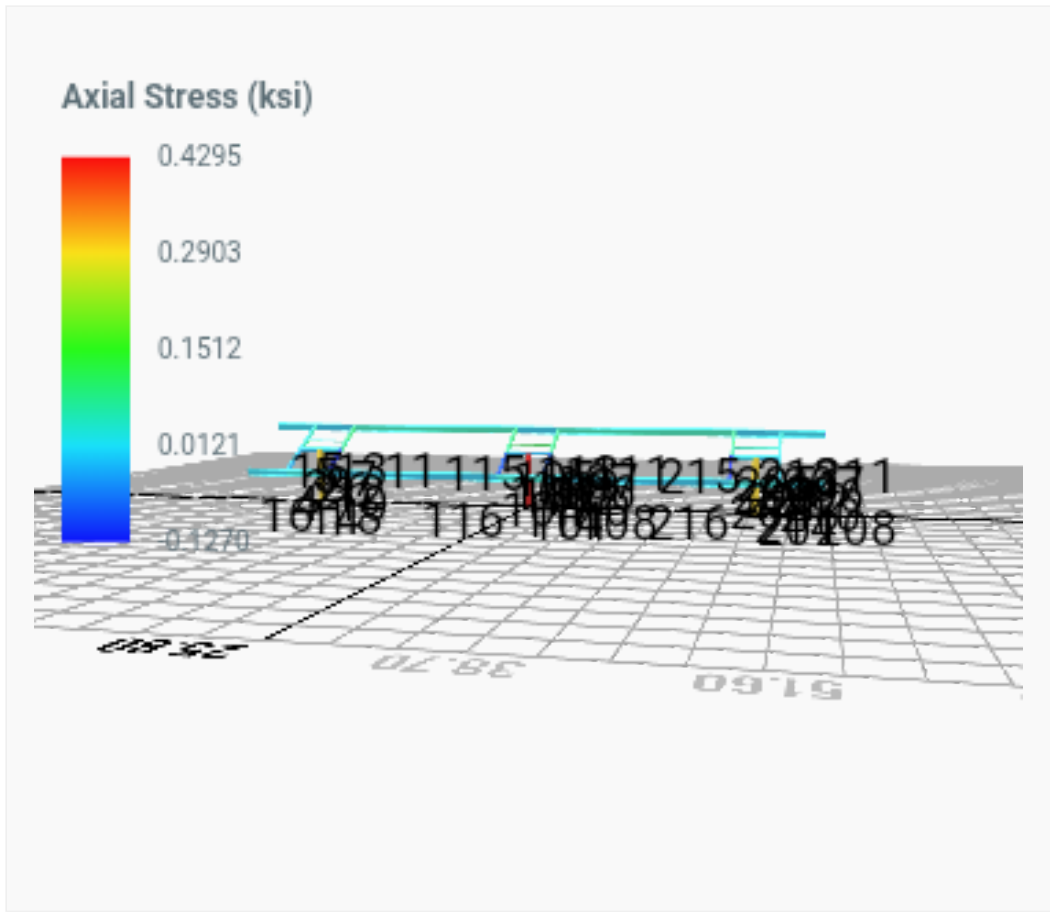


### Top Bending Stress Y (ksi)



### Shear Stress Y (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   | 0.0302  | 1.6792  | 0.1193  | 0.0658  | -0.0599 | -0.1019  |
| ULS: 2. D + L   | 0.0302  | 1.6792  | 0.1193  | 0.0658  | -0.0599 | -0.1019  |
| ULS: 3. D + (S or Lr or R)  | 0.0680  | 3.4013  | 0.2690  | 0.1488  | -0.1353 | -0.2590  |
| ULS: 3. D + (S or Lr or R)  | 0.0302  | 1.6792  | 0.1193  | 0.0658  | -0.0599 | -0.1019  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0585  | 2.9708  | 0.2316  | 0.1280  | -0.1165 | -0.2198  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0302  | 1.6792  | 0.1193  | 0.0658  | -0.0599 | -0.1019  |
| ULS: 5b. D + 0.7E   | 0.0302  | 1.6792  | 0.1193  | 0.0658  | -0.0599 | -0.1019  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S   | 0.0585  | 2.9708  | 0.2316  | 0.1280  | -0.1165 | -0.2198  |
| ULS: 8. 0.6D + 0.7E   | 0.0181  | 1.0075  | 0.0716  | 0.0395  | -0.0360 | -0.0612  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -2.3087 | 5.7124  | 0.5223  | 0.2172  | -0.6600 | 11.2969  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | -2.3087 | 5.7124  | 0.5223  | 0.2172  | -0.6600 | 11.2969  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 2.0348  | -1.7779 | -0.2222 | -0.0633 | 0.4505  | -9.7029  |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 1.7175  | -1.2137 | -0.1911 | -0.0499 | 0.4118  | -16.8432 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.6956 | 5.9957  | 0.5338  | 0.2416  | -0.5665 | 8.3294   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.6956 | 5.9957  | 0.5338  | 0.2416  | -0.5665 | 8.3294   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5620  | 0.3780  | -0.0246 | 0.0311  | 0.2664  | -7.4205  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.3240  | 0.8011  | -0.0013 | 0.0413  | 0.2374  | -12.7757 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.7240 | 4.7041  | 0.4216  | 0.1794  | -0.5099 | 8.4472   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.7240 | 4.7041  | 0.4216  | 0.1794  | -0.5099 | 8.4472   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5337  | -0.9136 | -0.1368 | -0.0310 | 0.3229  | -7.3027  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.2957  | -0.4905 | -0.1135 | -0.0209 | 0.2939  | -12.6579 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -2.3207 | 5.0407  | 0.4746  | 0.1909  | -0.6360 | 11.3377  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -2.3207 | 5.0407  | 0.4746  | 0.1909  | -0.6360 | 11.3377  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 2.0228  | -2.4496 | -0.2699 | -0.0897 | 0.4745  | -9.6621  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 1.7055  | -1.8853 | -0.2389 | -0.0762 | 0.4358  | -16.8024 |

### 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            | 9.5978              |
| Shear X          | -3.8980             |
| Shear Z          | 0.8924              |
| Moment X         | 0.3734              |
| Moment Y (Twist) | 1.1114              |
| Moment Z         | 28.2570             |

### 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            | 5.9957              |
| Shear X          | -2.3207             |
| Shear Z          | 0.5338              |
| Moment X         | 0.2416              |
| Moment Y (Twist) | 0.6600              |
| Moment Z         | 16.8432             |

## 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                              | -0.0602 | 2.2183 | 0.0001 | 0.0001 | -0.0003 | 0.2835 |
| ULS: 2. D + L                          | -0.0602 | 2.2183 | 0.0001 | 0.0001 | -0.0003 | 0.2835 |
| ULS: 3. D + (S or Lr or R)             | -0.1358 | 4.6153 | 0.0003 | 0.0002 | -0.0007 | 0.6108 |
| ULS: 3. D + (S or Lr or R)             | -0.0602 | 2.2183 | 0.0001 | 0.0001 | -0.0003 | 0.2835 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.1169 | 4.0160 | 0.0003 | 0.0002 | -0.0006 | 0.5290 |

| Name  | Fx      | Fy      | Fz      | Mx      | My      | Mz       |
|---|---------|---------|---------|---------|---------|----------|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | -0.0602 | 2.2183  | 0.0001  | 0.0001  | -0.0003 | 0.2835   |
| ULS: 5b. D + 0.7E   | -0.0602 | 2.2183  | 0.0001  | 0.0001  | -0.0003 | 0.2835   |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S   | -0.1169 | 4.0160  | 0.0003  | 0.0002  | -0.0006 | 0.5290   |
| ULS: 8. 0.6D + 0.7E   | -0.0361 | 1.3310  | 0.0001  | 0.0001  | -0.0002 | 0.1701   |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -3.3805 | 8.0045  | 0.0010  | 0.0014  | -0.0013 | 15.9477  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | -3.3805 | 8.0045  | 0.0010  | 0.0014  | -0.0013 | 15.9477  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 2.7857  | -2.7412 | -0.0006 | -0.0010 | 0.0005  | -12.8435 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 2.2778  | -1.8906 | -0.0004 | -0.0008 | 0.0006  | -21.4825 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.6071 | 8.3557  | 0.0009  | 0.0011  | -0.0013 | 12.2772  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.6071 | 8.3557  | 0.0009  | 0.0011  | -0.0013 | 12.2772  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 2.0176  | 0.2964  | -0.0003 | -0.0006 | -0.0000 | -9.3162  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.6367  | 0.9343  | -0.0002 | -0.0004 | 0.0000  | -15.7955 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.5504 | 6.5580  | 0.0008  | 0.0011  | -0.0010 | 12.0316  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.5504 | 6.5580  | 0.0008  | 0.0011  | -0.0010 | 12.0316  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 2.0742  | -1.5013 | -0.0004 | -0.0007 | 0.0003  | -9.5617  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.6933  | -0.8634 | -0.0003 | -0.0005 | 0.0003  | -16.0410 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -3.3564 | 7.1172  | 0.0009  | 0.0013  | -0.0011 | 15.8343  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -3.3564 | 7.1172  | 0.0009  | 0.0013  | -0.0011 | 15.8343  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 2.8098  | -3.6285 | -0.0006 | -0.0010 | 0.0006  | -12.9569 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 2.3019  | -2.7780 | -0.0005 | -0.0008 | 0.0007  | -21.5959 |

### 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            | 13.5046             |
| Shear X          | -5.6438             |
| Shear Z          | 0.0016              |
| Moment X         | 0.0024              |
| Moment Y (Twist) | 0.0021              |
| Moment Z         | 36.2766             |

### 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            | 8.3557              |
| Shear X          | -3.3805             |
| Shear Z          | 0.0010              |
| Moment X         | 0.0014              |
| Moment Y (Twist) | 0.0013              |
| Moment Z         | 21.5959             |

### Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

#### ASD Load Combination Results

| Name   | Fx      | Fy      | Fz      | Mx      | My      | Mz       |
|--|---------|---------|---------|---------|---------|----------|
| ULS: 1. D                                    | 0.0301  | 1.6792  | -0.1195 | -0.0657 | 0.0615  | -0.1016  |
| ULS: 2. D + L                                | 0.0301  | 1.6792  | -0.1195 | -0.0657 | 0.0615  | -0.1016  |
| ULS: 3. D + (S or Lr or R)                   | 0.0678  | 3.4013  | -0.2693 | -0.1484 | 0.1388  | -0.2583  |
| ULS: 3. D + (S or Lr or R)                   | 0.0301  | 1.6792  | -0.1195 | -0.0657 | 0.0615  | -0.1016  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | 0.0584  | 2.9708  | -0.2319 | -0.1277 | 0.1195  | -0.2191  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | 0.0301  | 1.6792  | -0.1195 | -0.0657 | 0.0615  | -0.1016  |
| ULS: 5b. D + 0.7E                            | 0.0301  | 1.6792  | -0.1195 | -0.0657 | 0.0615  | -0.1016  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S      | 0.0584  | 2.9708  | -0.2319 | -0.1277 | 0.1195  | -0.2191  |
| ULS: 8. 0.6D + 0.7E                          | 0.0181  | 1.0075  | -0.0717 | -0.0394 | 0.0369  | -0.0610  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.3088 | 5.7126  | -0.5233 | -0.2149 | 0.6638  | 11.2977  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.3088 | 5.7126  | -0.5233 | -0.2149 | 0.6638  | 11.2977  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only    | 2.0348  | -1.7780 | 0.2228  | 0.0617  | -0.4509 | -9.7030  |
| ULS: 5a. D + 0.6W_Wind uplift Case B only    | 1.7175  | -1.2138 | 0.1916  | 0.0485  | -0.4117 | -16.8484 |

| Name  | Fx      | Fy      | Fz      | Mx      | My      | Mz       |
|---|---------|---------|---------|---------|---------|----------|
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.6958 | 5.9958  | -0.5347 | -0.2397 | 0.5712  | 8.3303   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.6958 | 5.9958  | -0.5347 | -0.2397 | 0.5712  | 8.3303   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5619  | 0.3779  | 0.0248  | -0.0322 | -0.2648 | -7.4202  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.3239  | 0.8011  | 0.0014  | -0.0421 | -0.2354 | -12.7792 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.7241 | 4.7042  | -0.4223 | -0.1776 | 0.5132  | 8.4479   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -1.7241 | 4.7042  | -0.4223 | -0.1776 | 0.5132  | 8.4479   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5336  | -0.9137 | 0.1372  | 0.0299  | -0.3228 | -7.3026  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 1.2956  | -0.4905 | 0.1138  | 0.0200  | -0.2934 | -12.6617 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -2.3208 | 5.0409  | -0.4755 | -0.1886 | 0.6392  | 11.3384  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -2.3208 | 5.0409  | -0.4755 | -0.1886 | 0.6392  | 11.3384  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 2.0228  | -2.4497 | 0.2706  | 0.0880  | -0.4755 | -9.6623  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 1.7054  | -1.8855 | 0.2394  | 0.0748  | -0.4363 | -16.8077 |

### 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            | 9.5982              |
| Shear X          | -3.8982             |
| Shear Z          | -0.8940             |
| Moment X         | -0.3693             |
| Moment Y (Twist) | 1.1182              |
| Moment Z         | 28.2663             |

### 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            | 5.9958              |
| Shear X          | -2.3208             |
| Shear Z          | -0.5347             |
| Moment X         | -0.2397             |
| Moment Y (Twist) | 0.6638              |
| Moment Z         | 16.8484             |

# Project Details

Design Code: AISC 360-16 LRFD  
 Provision: LRFD  
 Country: United States  
 User Name: sales@mtsolar.us  
 Project Name: MTSOLAR\_0AC09DHIHG47F  
 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       |  |  |  |  |
| 7  | 6in Pipe Sch 40 | 6.63   | 0.28       |  |  |  |  |

| Section Dimensions |  |  |  |  |  |  |  |
|--------------------|--|--|--|--|--|--|--|
|                    |  |  |  |  |  |  |  |

| 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   |  |

| Section Dimensions |  |  |  |  |  |  |  |
|--------------------|--|--|--|--|--|--|--|
|                    |  |  |  |  |  |  |  |

| 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 <sup>2</sup> ) | J (in <sup>4</sup> ) | $I_{y0}$ (in <sup>4</sup> ) | $I_{z0}$ (in <sup>4</sup> ) | $I_w$ (in <sup>6</sup> ) | $S_{y0}$ (in <sup>3</sup> ) | $S_{z0}$ (in <sup>3</sup> ) |





|     |        |        |       |       |       |       |
|-----|--------|--------|-------|-------|-------|-------|
| 101 | 251.16 | 203.89 | 42.30 | 42.30 | 75.35 | 75.35 |
| 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 | 123.95 | 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 | 123.95 | 32.87 | 6.12  | 40.24 | 43.62 |
| 112 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 85.85  | 23.47 | 6.12  | 40.24 | 43.62 |
| 114 | 133.20 | 85.85  | 23.08 | 6.12  | 40.24 | 43.62 |
| 115 | 133.20 | 31.52  | 16.54 | 6.12  | 40.24 | 43.62 |
| 116 | 133.20 | 31.52  | 16.75 | 6.12  | 40.24 | 43.62 |
| 201 | 251.16 | 203.89 | 42.30 | 42.30 | 75.35 | 75.35 |
| 202 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 203 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 204 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 205 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 206 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 207 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 208 | 133.20 | 102.39 | 32.87 | 6.12  | 40.24 | 43.62 |
| 209 | 66.48  | 58.89  | 3.82  | 3.82  | 19.94 | 19.94 |
| 210 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 211 | 133.20 | 102.39 | 32.87 | 6.12  | 40.24 | 43.62 |
| 212 | 198.33 | 182.14 | 21.95 | 21.95 | 59.50 | 59.50 |
| 213 | 133.20 | 85.85  | 27.50 | 6.12  | 40.24 | 43.62 |
| 214 | 133.20 | 85.85  | 25.85 | 6.12  | 40.24 | 43.62 |
| 215 | 133.20 | 31.52  | 17.09 | 6.12  | 40.24 | 43.62 |
| 216 | 133.20 | 31.52  | 17.06 | 6.12  | 40.24 | 43.62 |

## 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         | δ            | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|--------------|--------------|--------|
| 1         | 0.047 | 0.668          | 0.091          | 0.051          | 0.012          | 0.674                               | #16      | 0.267        | Not Required | Pass   |
| 2         | 0.003 | 0.280          | 0.142          | 0.066          | 0.029          | 0.423                               | #13      | 0.171        | Not Required | Pass   |
| 3         | 0.005 | 0.511          | 0.022          | 0.050          | 0.006          | 0.534                               | #13      | 0.045        | Not Required | Pass   |
| 4         | 0.003 | 0.508          | 0.068          | 0.051          | 0.016          | 0.577                               | #13      | 0.120        | Not Required | Pass   |
| 5         | 0.004 | 0.317          | 0.031          | 0.051          | 0.008          | 0.331                               | #13      | 0.074        | Not Required | Pass   |
| 6         | 0.006 | 0.690          | 0.083          | 0.071          | 0.022          | 0.757                               | #13      | 0.045        | Not Required | Pass   |
| 7         | 0.007 | 0.428          | 0.115          | 0.069          | 0.030          | 0.457                               | #13      | 0.074        | Not Required | Pass   |
| 8         | 0.003 | 0.141          | 0.095          | 0.043          | 0.010          | 0.171                               | #13      | 0.095        | Not Required | Pass   |
| 9         | 0.004 | 0.061          | 0.074          | 0.002          | 0.004          | 0.136                               | #13      | 0.204        | Not Required | Pass   |
| 10        | 0.008 | 0.668          | 0.099          | 0.067          | 0.021          | 0.687                               | #13      | 0.080        | Not Required | Pass   |
| 11        | 0.005 | 0.138          | 0.098          | 0.045          | 0.010          | 0.160                               | #13      | 0.095        | Not Required | Pass   |
| 12        | 0.002 | 0.456          | 0.192          | 0.093          | 0.036          | 0.649                               | #13      | 0.053        | Not Required | Pass   |
| 13        | 0.007 | 0.115          | 0.246          | 0.060          | 0.013          | 0.304                               | #21      | 0.286        | Not Required | Pass   |
| 14        | 0.005 | 0.110          | 0.243          | 0.058          | 0.013          | 0.279                               | #21      | 0.190        | Not Required | Pass   |
| 15        | 0.000 | 0.020          | 0.024          | 0.017          | 0.002          | 0.040                               | #21      | Not Required | Not Required | Pass   |

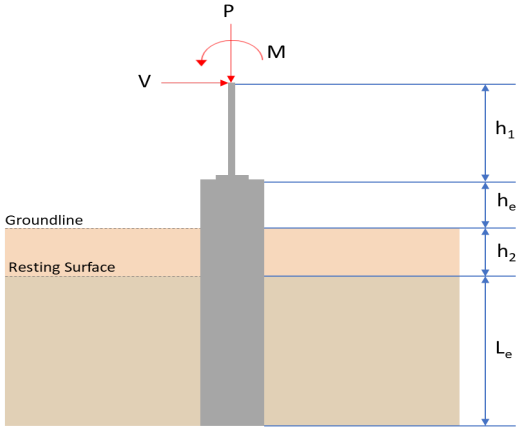
|     |       |       |       |       |       |       |     |              |              |      |
|-----|-------|-------|-------|-------|-------|-------|-----|--------------|--------------|------|
| 15  | 0.000 | 0.020 | 0.024 | 0.017 | 0.003 | 0.040 | #21 | Not Required | Not Required | Pass |
| 16  | 0.000 | 0.020 | 0.024 | 0.017 | 0.003 | 0.040 | #21 | Not Required | Not Required | Pass |
| 101 | 0.066 | 0.855 | 0.000 | 0.075 | 0.000 | 0.864 | #32 | 0.267        | Not Required | Pass |
| 102 | 0.002 | 0.529 | 0.249 | 0.113 | 0.047 | 0.779 | #13 | 0.035        | Not Required | Pass |
| 103 | 0.007 | 0.841 | 0.040 | 0.084 | 0.006 | 0.866 | #13 | 0.045        | Not Required | Pass |
| 104 | 0.006 | 0.858 | 0.104 | 0.086 | 0.022 | 0.902 | #13 | 0.080        | Not Required | Pass |
| 105 | 0.006 | 0.523 | 0.106 | 0.084 | 0.027 | 0.539 | #13 | 0.074        | Not Required | Pass |
| 106 | 0.007 | 0.842 | 0.040 | 0.084 | 0.006 | 0.866 | #13 | 0.045        | Not Required | Pass |
| 107 | 0.006 | 0.523 | 0.106 | 0.084 | 0.027 | 0.539 | #13 | 0.074        | Not Required | Pass |
| 108 | 0.003 | 0.067 | 0.098 | 0.058 | 0.010 | 0.142 | #21 | 0.095        | Not Required | Pass |
| 109 | 0.008 | 0.076 | 0.048 | 0.001 | 0.000 | 0.127 | #13 | 0.204        | Not Required | Pass |
| 110 | 0.006 | 0.858 | 0.104 | 0.086 | 0.022 | 0.902 | #13 | 0.080        | Not Required | Pass |
| 111 | 0.005 | 0.089 | 0.097 | 0.056 | 0.010 | 0.129 | #21 | 0.095        | Not Required | Pass |
| 112 | 0.002 | 0.530 | 0.249 | 0.113 | 0.047 | 0.779 | #13 | 0.035        | Not Required | Pass |
| 113 | 0.007 | 0.260 | 0.245 | 0.071 | 0.013 | 0.435 | #21 | 0.286        | Not Required | Pass |
| 114 | 0.008 | 0.303 | 0.247 | 0.073 | 0.013 | 0.457 | #21 | 0.286        | Not Required | Pass |
| 115 | 0.020 | 0.360 | 0.134 | 0.056 | 0.010 | 0.442 | #13 | 0.728        | Not Required | Pass |
| 116 | 0.013 | 0.341 | 0.135 | 0.058 | 0.010 | 0.422 | #13 | 0.728        | Not Required | Pass |
| 201 | 0.047 | 0.668 | 0.091 | 0.051 | 0.012 | 0.674 | #16 | 0.267        | Not Required | Pass |
| 202 | 0.002 | 0.456 | 0.192 | 0.093 | 0.036 | 0.650 | #13 | 0.053        | Not Required | Pass |
| 203 | 0.006 | 0.691 | 0.083 | 0.071 | 0.022 | 0.758 | #13 | 0.045        | Not Required | Pass |
| 204 | 0.008 | 0.669 | 0.099 | 0.067 | 0.021 | 0.688 | #13 | 0.080        | Not Required | Pass |
| 205 | 0.007 | 0.428 | 0.115 | 0.069 | 0.030 | 0.458 | #13 | 0.074        | Not Required | Pass |
| 206 | 0.005 | 0.511 | 0.022 | 0.050 | 0.006 | 0.534 | #13 | 0.045        | Not Required | Pass |
| 207 | 0.004 | 0.317 | 0.031 | 0.051 | 0.008 | 0.331 | #13 | 0.074        | Not Required | Pass |
| 208 | 0.000 | 0.020 | 0.024 | 0.017 | 0.003 | 0.040 | #21 | Not Required | Not Required | Pass |
| 209 | 0.004 | 0.061 | 0.074 | 0.002 | 0.004 | 0.137 | #13 | 0.204        | Not Required | Pass |
| 210 | 0.003 | 0.508 | 0.068 | 0.051 | 0.016 | 0.577 | #13 | 0.120        | Not Required | Pass |
| 211 | 0.000 | 0.020 | 0.024 | 0.017 | 0.003 | 0.040 | #21 | Not Required | Not Required | Pass |
| 212 | 0.003 | 0.280 | 0.142 | 0.066 | 0.029 | 0.423 | #13 | 0.171        | Not Required | Pass |
| 213 | 0.007 | 0.115 | 0.246 | 0.060 | 0.013 | 0.304 | #21 | 0.190        | Not Required | Pass |
| 214 | 0.005 | 0.110 | 0.242 | 0.058 | 0.013 | 0.279 | #21 | 0.286        | Not Required | Pass |
| 215 | 0.020 | 0.380 | 0.131 | 0.045 | 0.010 | 0.461 | #13 | 0.728        | Not Required | Pass |
| 216 | 0.013 | 0.369 | 0.134 | 0.043 | 0.010 | 0.454 | #13 | 0.728        | 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                                    |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
|----------------|--|--|---|--|---|---|---|----------|---------|----------------|-----|------|-----------|-------|-------|-------------|--------|--------|-------------|-------|-------|---------------|-------|-------|---------------|--------|--------|--|
|                | <p><b>SkyCiv Foundation Design</b><br/>Pile Foundation</p> <p><b>Design Information :</b><br/>Design code : IBC 2021 (International Building Code)<br/>Unit System : Imperial</p>  |  |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
|                | <p><b>Pile Input</b></p>  <p><b>Geometry</b></p> <p>Pile shape: round<br/> <math>D = 36</math> in - Pile diameter<br/> <math>L = 7.25</math> ft - Total pile length<br/> <math>h_1 = 0</math> ft - Lateral load height from the top of the pile,<br/> <math>h_2 = 0</math> ft - Depth to resisting surface<br/> <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>5.996</td> <td>9.598</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.321</td> <td>-3.898</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.534</td> <td>0.892</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.242</td> <td>0.373</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>16.843</td> <td>28.257</td> </tr> </tbody> </table> <p><b>Material Properties</b></p> <p><math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p> | 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 | Load Component | ASD | LRFD | $P$ (kip) | 5.996 | 9.598 | $V_x$ (kip) | -2.321 | -3.898 | $V_z$ (kip) | 0.534 | 0.892 | $M_x$ (kipft) | 0.242 | 0.373 | $M_z$ (kipft) | 16.843 | 28.257 |  |
| 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                                     |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| Load Component | ASD  | LRFD                                       |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| $P$ (kip)      | 5.996  | 9.598                                      |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| $V_x$ (kip)    | -2.321   | -3.898                                     |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| $V_z$ (kip)    | 0.534  | 0.892                                      |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| $M_x$ (kipft)  | 0.242  | 0.373                                      |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
| $M_z$ (kipft)  | 16.843   | 28.257                                     |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |
|                | <p><b>Required depth to resist lateral loads (ASD)</b></p> <p><math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.321 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.77367 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p>   |  |   |  |   |   |   |          |         |                |     |      |           |       |       |             |        |        |             |       |       |               |       |       |               |        |        |  |

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

$$M_o = \frac{(16.843 \text{ kipft}) + ((-2.321 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.6143 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.2792 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.534 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.178 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.242 \text{ kipft}) + ((0.534 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.080667 \text{ kipft/ft}$$

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:

$L_{e,z} = 4.3703 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.2792 \text{ ft}), (4.3703 \text{ ft})]$$

$$L_{e,req} = 6.279 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.25 \text{ ft}$$

Ratio - Embedded depth

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

$$Ratio = \frac{(6.279 \text{ ft})}{(7.25 \text{ ft})}$$

$$Ratio = 0.86607$$

Status: **PASS**  
Ratio: **0.870**

### 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

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

$$q = \frac{(5.996 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.84826 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.84826 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.42413$$

Status: **PASS**  
Ratio: **0.420**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.4167$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.77367 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.6143 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.6143 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (5.6143 \text{ kipft/ft})) + (4 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.0749 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.6143 \text{ kipft/ft})) + (3 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (5.6143 \text{ kipft/ft})) + (2 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = 0.1263 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (5.6143 \text{ kipft/ft})) + ((-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = 1.0076 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0749 \text{ ft})}{2}$$

$$p_a = 0.38061 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.1263 \text{ kip/ft}^2)}{(0.38061 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.33182$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.25 \text{ ft})$$

$$p_s = 1.0875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.0076 \text{ kip/ft}^2)}{(1.0875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92657$$

Status: **PASS**  
Ratio: **0.330**

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

**Considering z-direction:**

$H_o = 0.178 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.080667 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.080667 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (0.178 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (0.080667 \text{ kipft/ft})) + (4 \times (0.178 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.3857 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.080667 \text{ kipft/ft})) + (3 \times (0.178 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (0.080667 \text{ kipft/ft})) + (2 \times (0.178 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = 0.13965 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.080667 \text{ kipft/ft})) + ((0.178 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = 0.26033 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3857 \text{ ft})}{2}$$

$$p_a = 0.40393 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.13965 \text{ kip/ft}^2)}{(0.40393 \text{ kip/ft}^2)}$$

$$(0.7000 \text{ kip/ft}^2)$$

$$\text{Ratio} = 0.34574$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.25 \text{ ft})$$

$$p_s = 1.0875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

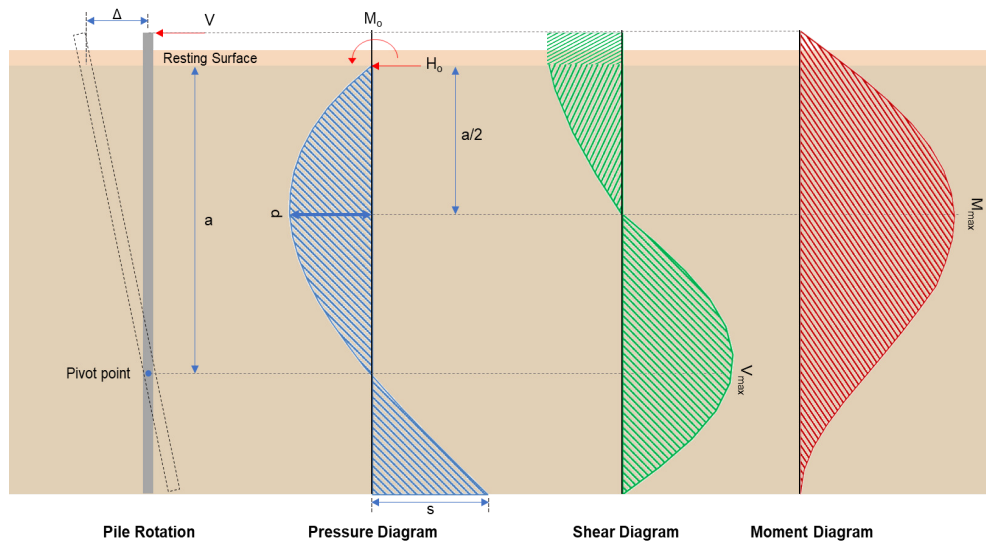
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(0.26033 \text{ kip/ft}^2)}{(1.0875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.23938$$

Status: **PASS**  
Ratio: **0.350**

Status: **PASS**  
Ratio: **0.240**



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.898 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.2993 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(28.257 \text{ kipft}) + ((-3.898 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.419 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.419 \text{ kipft/ft})}{(-1.2993 \text{ kip/ft})}$$

$$E = 7.2491 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.419 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-1.2993 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (9.419 \text{ kipft/ft})) + (4 \times (-1.2993 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.075 \text{ ft}$$

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

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

$$V_{max} = ((-1.2993 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (7.2491 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.075 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (7.2491 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.075 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4713 \text{ kip}$$

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

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

$$M_{max} = ((-1.2993 \text{ kip/ft}) \times (36 \text{ in}) \times (7.25 \text{ ft})) \times \left[ \left( \frac{(7.2491 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (7.2491 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (7.2491 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 31.787 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.892 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.29733 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.373 \text{ kipft}) + ((0.892 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.12433 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.12433 \text{ kipft/ft})}{(0.29733 \text{ kip/ft})}$$

$$E = 0.41816 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.12433 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (0.29733 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (0.12433 \text{ kipft/ft})) + (4 \times (0.29733 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.3894 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((0.29733 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (0.41816 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.3894 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (0.41816 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.3894 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.70045 \text{ kip}$$

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

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

$$M_{max} = ((0.29733 \text{ kip/ft}) \times (36 \text{ in}) \times (7.25 \text{ ft})) \times \left[ \left( \frac{(0.41816 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.3894 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (0.41816 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.3894 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (0.41816 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.3894 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.9721 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(9.598 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.073 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37.073 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

$$(1.8322 \text{ in}^2)$$

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|   |   |  |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = \frac{\lambda}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>1.000</b></p> |
| <p>22.4.2.2</p>                                     | <p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\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))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(9.598 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0076545</math></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.010</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p> |  |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 9.598 \text{ kip} \rightarrow 9598 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(9598 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.067 \text{ kip}$$

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

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.067 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.067 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - 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

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

$$\phi V_n = (0.65) \times ((76.067 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.254 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 9.4713 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(9.4713 \text{ kip})}{(74.254 \text{ kip})}$$

$$Ratio = 0.12755$$

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

**Considering z-direction:**

$V_{max} = 0.70045 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.70045 \text{ kip})}{(74.254 \text{ kip})}$$

$$Ratio = 0.0094331$$

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

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

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

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

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

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:**

$M_{max} = 31.787 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(31.787 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.51248$$

Status: **PASS**  
Ratio: **0.510**

**Considering z-direction:**

$M_{max} = 1.9721 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(1.9721 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.031794$$

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

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

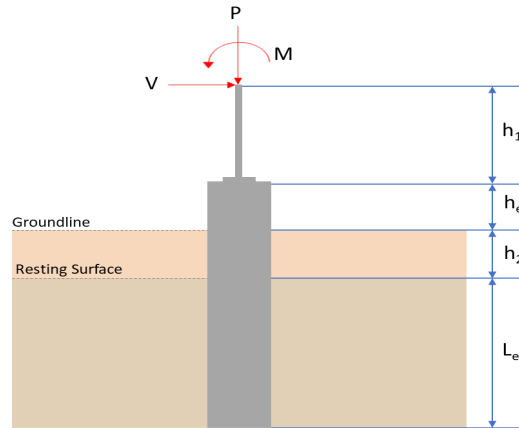
## SkyCiv Foundation Design

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

$L = 7.25$  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)      | 5.996  | 9.598  |
| $V_x$ (kip)    | -2.321 | -3.898 |
| $V_z$ (kip)    | -0.535 | -0.894 |
| $M_x$ (kipft)  | -0.240 | -0.369 |
| $M_z$ (kipft)  | 16.848 | 28.266 |

### 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,

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

$$H_o = \frac{(-2.321 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.77367 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(16.848 \text{ kipft}) + ((-2.321 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.616 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.2803 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.535 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.17833 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.24 \text{ kipft}) + ((-0.535 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.08 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.58606 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2803 \text{ ft}), (0.58606 \text{ ft})]$$

$$L_{e,req} = 6.28 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.25 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.28 \text{ ft})}{(7.25 \text{ ft})}$$

$$\text{Ratio} = 0.86621$$

Status: **PASS**  
Ratio: **0.870**

### 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

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

$$q = \frac{(5.996 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.84826 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.84826 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.42413$$

Status: **PASS**  
Ratio: **0.420**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.4167$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.77367 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.616 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.616 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (5.616 \text{ kipft/ft})) + (4 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.0748 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.616 \text{ kipft/ft})) + (3 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (5.616 \text{ kipft/ft})) + (2 \times (-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = 0.12648 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (5.616 \text{ kipft/ft})) + ((-0.77367 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = 1.0082 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0748 \text{ ft})}{2}$$

$$p_a = 0.38061 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.12648 \text{ kip/ft}^2)}{(0.38061 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.33231$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.25 \text{ ft})$$

$$p_s = 1.0875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.0082 \text{ kip/ft}^2)}{(1.0875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92712$$

Status: **PASS**  
Ratio: **0.330**

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

**Considering z-direction:**

$H_o = -0.17833 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.08 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.08 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-0.17833 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (0.08 \text{ kipft/ft})) + (4 \times (-0.17833 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.3862 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.08 \text{ kipft/ft})) + (3 \times (-0.17833 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (0.08 \text{ kipft/ft})) + (2 \times (-0.17833 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = -0.12099 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.08 \text{ kipft/ft})) + ((-0.17833 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = -0.20314 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3862 \text{ ft})}{2}$$

$$p_a = 0.40396 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.12099 \text{ kip/ft}^2)}{(0.40396 \text{ kip/ft}^2)}$$

$$(0.7000 \text{ kip/ft}^2)$$

$$\text{Ratio} = -0.29952$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.25 \text{ ft})$$

$$p_s = 1.0875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

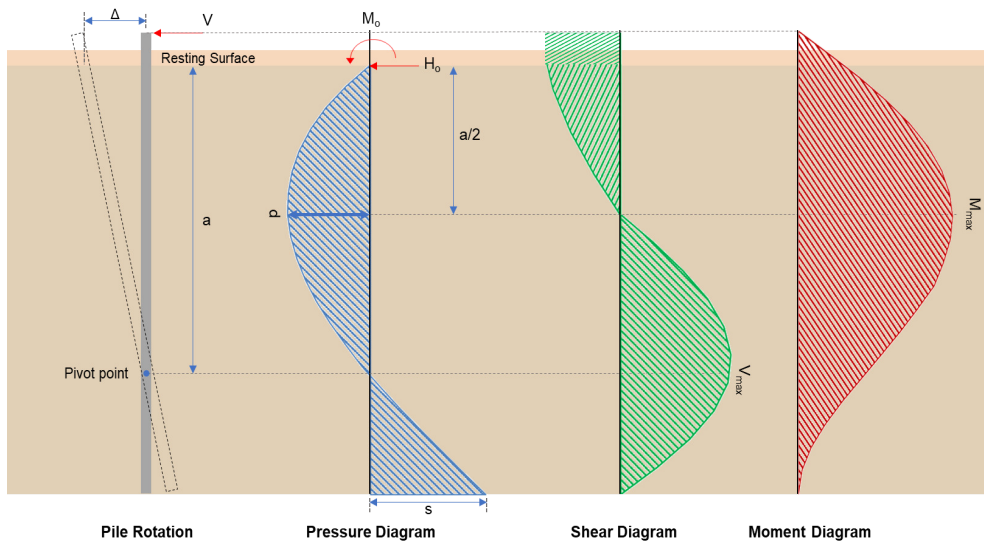
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(-0.20314 \text{ kip/ft}^2)}{(1.0875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.1868$$

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

Status: **PASS**  
Ratio: **-0.190**



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.898 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.2993 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(28.266 \text{ kipft}) + ((-3.898 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.422 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.422 \text{ kipft/ft})}{(-1.2993 \text{ kip/ft})}$$

$$E = 7.2514 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.422 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-1.2993 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (9.422 \text{ kipft/ft})) + (4 \times (-1.2993 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.075 \text{ ft}$$

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

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

$$V_{max} = ((-1.2993 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (7.2514 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.075 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (7.2514 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.075 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4735 \text{ kip}$$

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

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

$$M_{max} = ((-1.2993 \text{ kip/ft}) \times (36 \text{ in}) \times (7.25 \text{ ft})) \times \left[ \left( \frac{(7.2514 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (7.2514 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (7.2514 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.075 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 31.795 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.894 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.298 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.369 \text{ kipft}) + ((-0.894 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.123 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.123 \text{ kipft/ft})}{(-0.298 \text{ kip/ft})}$$

$$E = 0.41275 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.123 \text{ kipft/ft}) \times (7.25 \text{ ft})) + (3 \times (-0.298 \text{ kip/ft}) \times (7.25 \text{ ft})^2)}{(6 \times (0.123 \text{ kipft/ft})) + (4 \times (-0.298 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.39 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((-0.298 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (0.41275 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.39 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (0.41275 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.39 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.70089 \text{ kip}$$

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

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

$$M_{max} = ((-0.298 \text{ kip/ft}) \times (36 \text{ in}) \times (7.25 \text{ ft})) \times \left[ \left( \frac{(0.41275 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.39 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (0.41275 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.39 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (0.41275 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.39 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.9724 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(9.598 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.073 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37.073 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|   |   |  |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = \frac{\lambda}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>1.000</b></p> |
| <p>22.4.2.2</p>                                     | <p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\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))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(9.598 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0076545</math></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.010</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p> |  |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 9.598 \text{ kip} \rightarrow 9598 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(9598 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.067 \text{ kip}$$

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

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.067 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.067 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - 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

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

$$\phi V_n = (0.65) \times ((76.067 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.254 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 9.4735 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(9.4735 \text{ kip})}{(74.254 \text{ kip})}$$

$$Ratio = 0.12758$$

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

**Considering z-direction:**

$V_{max} = 0.70089 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.70089 \text{ kip})}{(74.254 \text{ kip})}$$

$$Ratio = 0.009439$$

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

**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

$\phi M_{n,2}$

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

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

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

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:**

$M_{max} = 31.795 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(31.795 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.5126$$

Status: **PASS**  
Ratio: **0.510**

**Considering z-direction:**

$M_{max} = 1.9724 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(1.9724 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.031799$$

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

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

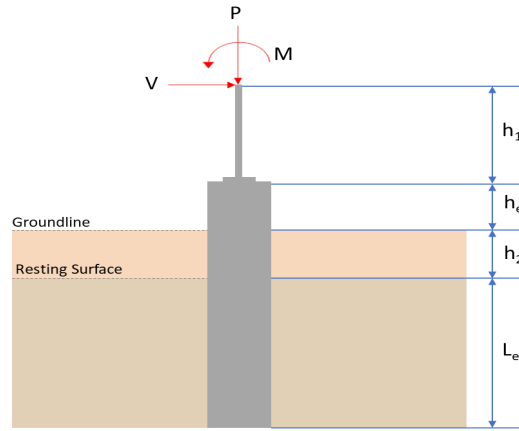
## SkyCiv Foundation Design

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

$L = 7.5$  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)      | 8.356  | 13.505 |
| $V_x$ (kip)    | -3.380 | -5.644 |
| $V_z$ (kip)    | 0.001  | 0.002  |
| $M_x$ (kipft)  | 0.001  | 0.002  |
| $M_z$ (kipft)  | 21.596 | 36.277 |

### 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,

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

$$H_o = \frac{(-3.38 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1267 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(21.596 \text{ kipft}) + ((-3.38 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.1987 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.2352 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.001 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.00033333 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

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

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

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:

$L_{e,z} = 0.37602 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2352 \text{ ft}), (0.37602 \text{ ft})]$$

$$L_{e,req} = 6.235 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.235 \text{ ft})}{(7.5 \text{ ft})}$$

$$\text{Ratio} = 0.83133$$

Status: **PASS**  
Ratio: **0.830**

### 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

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

$$q = \frac{(8.356 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1821 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.1821 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.59107$$

Status: **PASS**  
Ratio: **0.590**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -1.1267 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 7.1987 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (7.1987 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-1.1267 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (7.1987 \text{ kipft/ft})) + (4 \times (-1.1267 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.2744 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.1987 \text{ kipft/ft})) + (3 \times (-1.1267 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (7.1987 \text{ kipft/ft})) + (2 \times (-1.1267 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.052916 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (7.1987 \text{ kipft/ft})) + ((-1.1267 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 0.99651 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2744 \text{ ft})}{2}$$

$$p_a = 0.39558 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.052916 \text{ kip/ft}^2)}{(0.39558 \text{ kip/ft}^2)}$$

$$Ratio = 0.13377$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.99651 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.88579$$

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

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

**Considering z-direction:**

$H_o = 0.00033333 \text{ kip/ft}$  - Lateral force per length of pile.

$M_o = 0.00033333 \text{ kipft/ft}$  - Overturning moment per length of pile.

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

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

$$a = \frac{(4 \times (0.00033333 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (0.00033333 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.00033333 \text{ kipft/ft})) + (4 \times (0.00033333 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.5208 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.00033333 \text{ kipft/ft})) + (3 \times (0.00033333 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (0.00033333 \text{ kipft/ft})) + (2 \times (0.00033333 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.00027235 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.00033333 \text{ kipft/ft})) + ((0.00033333 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 0.00053059 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5208 \text{ ft})}{2}$$

$$p_a = 0.41406 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.00027235 \text{ kip/ft}^2)}{(0.41406 \text{ kip/ft}^2)}$$

(0.00053059 kip/ft<sup>2</sup>)

$$Ratio = 0.00065774$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

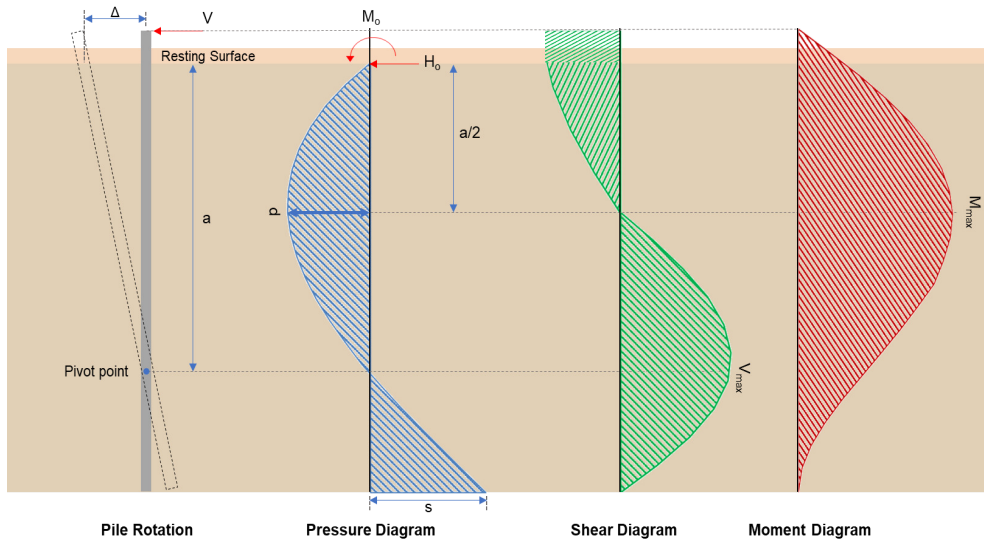
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.00053059 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.00047164$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.644 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.8813 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(36.277 \text{ kipft}) + ((-5.644 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 12.092 \text{ kipft/ft}$$

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

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

$$E = \frac{(12.092 \text{ kipft/ft})}{(-1.8813 \text{ kip/ft})}$$

$$E = 6.4275 \text{ ft}$$

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

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

$$a = \frac{(4 \times (12.092 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-1.8813 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (12.092 \text{ kipft/ft})) + (4 \times (-1.8813 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.2735 \text{ ft}$$

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

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

$$V_{max} = ((-1.8813 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (6.4275 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.2735 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (6.4275 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.2735 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.292 \text{ kip}$$

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

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

$$M_{max} = ((-1.8813 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[ \left( \frac{(6.4275 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.2735 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (6.4275 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.2735 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (6.4275 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.2735 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 42.291 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.002 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.00066667 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.002 \text{ kipft}) + ((0.002 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.00066667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.00066667 \text{ kipft/ft})}{(0.00066667 \text{ kip/ft})}$$

$$E = 1 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.00066667 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (0.00066667 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.00066667 \text{ kipft/ft})) + (4 \times (0.00066667 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.5208 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((0.00066667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (1 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.5208 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (1 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.5208 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0018291 \text{ kip}$$

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

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

$$M_{max} = ((0.00066667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.5 \text{ ft})) \times \left[ \left( \frac{(1 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.5208 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (1 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.5208 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (1 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.5208 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.005539 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

$f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,

$\phi = 0.65$  - Reduction factor for axial strength,

Table 22.4.2.1

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

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

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{(13.505 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2)), \frac{(13.505 \text{ kip})}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.951 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-36.951 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

|   |   |  |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = \frac{\lambda}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>1.000</b></p> |
| <p>22.4.2.2</p>                                     | <p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\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))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(13.505 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.01077</math></p>  | <p>Status: <b>PASS</b><br/>Ratio: <b>0.010</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p> |  |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 13.505 \text{ kip} \rightarrow 13505 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(13505 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.731 \text{ kip}$$

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

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.731 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.731 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - 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

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

$$\phi V_n = (0.65) \times ((76.731 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.686 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 12.292 \text{ kip}$  - Maximum shear force in the x-direction,

*Ratio* - Capacity

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

$$Ratio = \frac{(12.292 \text{ kip})}{(74.686 \text{ kip})}$$

$$Ratio = 0.16459$$

Status: **PASS**  
Ratio: **0.160**

**Considering z-direction:**

$V_{max} = 0.0018291 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.0018291 \text{ kip})}{(74.686 \text{ kip})}$$

$$Ratio = 0.000024491$$

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

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - 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

$\phi M_{n,2}$

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

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

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

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:**

$M_{max} = 42.291 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(42.291 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.68182$$

Status: **PASS**  
Ratio: **0.680**

**Considering z-direction:**

$M_{max} = 0.005539 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(0.005539 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0000893$$

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