

## Project Details



**Project Name:** MTSOLAR\_AB2044KCL68CA

**Date:** Sat Sep 21 2024

**Location:** 253 Flatiron Trl, Cameron, MT 59720,  
USA

**Number of Modules:** 28

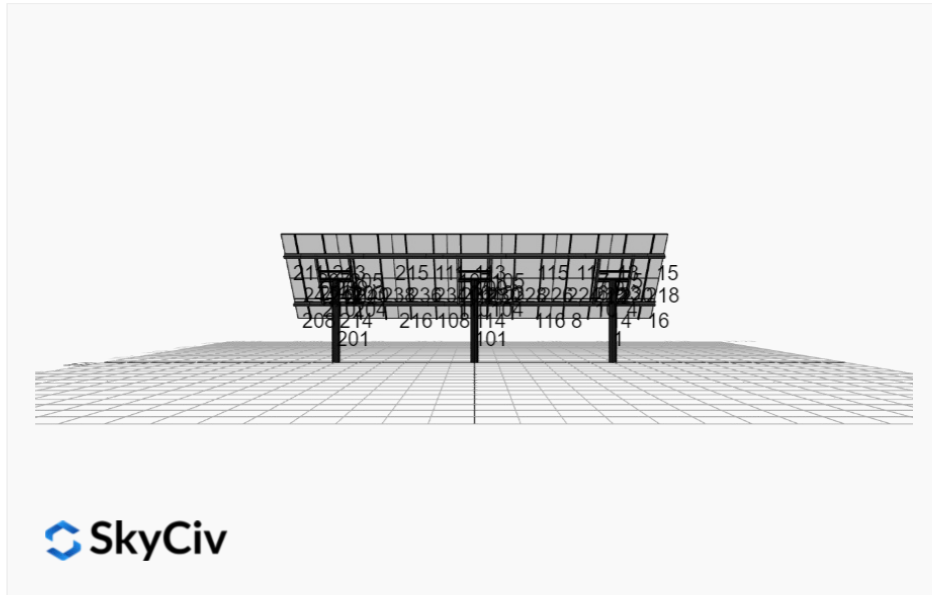
**Unique ID:** 3P-17-10TOP-SD-24-L-4Hx7W-EI8A

**Number of Poles:** 3

**Date Sold:**

**Dealer:** \_\_\_\_\_

\_\_\_\_\_



|                      |          |
|----------------------|----------|
| Array Dimensions N/S | 13.17 ft |
| Array Dimensions E/W | 45.50 ft |
| Winter Tilt Angle    | 50       |
| Front Edge Clearance | 5 ft     |

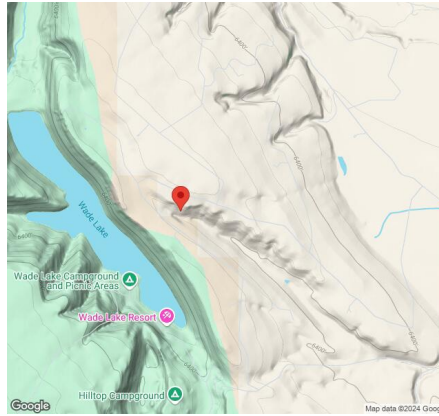
### MT Solar Bill of Materials (3P-17-10TOP-SD-24-L-4Hx7W-EI8A)

| Part               | Short Description      | BOM Qty |
|--------------------|------------------------|---------|
| MTS-PC-10          | 10IN Pole Cap Assembly | 3       |
| MTS-HF-SD          | H-Frame Assembly-SD    | 3       |
| MTS-SD-Wing-24     | 24IN SD Wing           | 4       |
| MTS-SD-Splice-57   | 57IN SD Splice         | 8       |
| MTS-CLAMP-HOOK-4PK | Hook Clamp             | 7       |

### Rail Bill of Materials

| Part             | Qty |
|------------------|-----|
| Rails (156in)    | 14  |
| Rail Attachment  | 28  |
| Module Mid Clamp | 42  |
| Module End Clamp | 28  |
| Ground Lug       | 7   |

## Site Details:



**Site Address:** 253 Flatiron Trl, Cameron, MT 59720, USA

### Array Specification

|                                    |           |
|------------------------------------|-----------|
| <b>Duty Classification:</b>        | SD        |
| <b>Module Width:</b>               | 39.00 in  |
| <b>Module Length:</b>              | 77.00in   |
| <b>Number of Rows:</b>             | 4         |
| <b>Number of Columns:</b>          | 7         |
| <b>Total Number of Modules:</b>    | 28        |
| <b>Winter Tilt Angle:</b>          | 50        |
| <b>Front Edge Clearance:</b>       | 5         |
| <b>Total Array Height at Tilt:</b> | 15.09 ft  |
| <b>Total Frame Length:</b>         | 45.50 ft  |
| <b>Frame Weight:</b>               | 3014 lbs  |
| <b>Array Dimensions N/S:</b>       | 13.17 ft  |
| <b>Array Dimensions E/W:</b>       | 45.50 ft  |
| <b>Rail Length:</b>                | 158.00 in |
| <b>Rail Spacing:</b>               | 3.25 ft   |

### Support Specifications

|                                 |                  |
|---------------------------------|------------------|
| <b>Pole Size:</b>               | 10in Pipe Sch 40 |
| <b>Pole Length above Grade:</b> | 10.04 ft         |
| <b>Number of Poles:</b>         | 3                |
| <b>Pole Spacing:</b>            | 17 ft            |

### Foundation Specifications

|  |   |
|--|---|
| <b>Foundation Type:</b>                | Square  |
| <b>Foundation Dimensions:</b>          | 48 x 48 in  |
| <b>Foundation Depth (below grade):</b> | Pile 1: 5.50 ft<br>Pile 2: 6.00 ft<br>Pile 3: 5.50 ft |
| <b>Foundation Volume:</b>              | 10.074 y <sup>3</sup>                                 |

### Site Info

|                             |  |
|-----------------------------|--|
| <b>Risk Category:</b>       | I  |
| <b>Exposure:</b>            | C  |
| <b>Soil Classification:</b> | sand                                     |
| <b>Site Location:</b>       | 253 Flatiron Trl, Cameron, MT 59720, USA |
| <b>Wind Speed:</b>          | 110 mph                                  |
| <b>Snow Load:</b>           | 40 psf                                   |

### **Design Disclaimer**

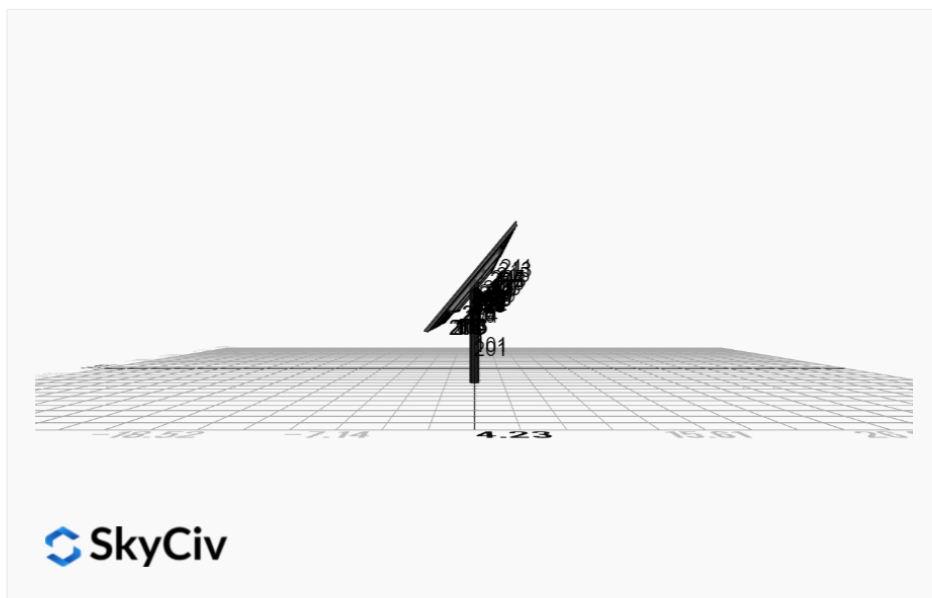
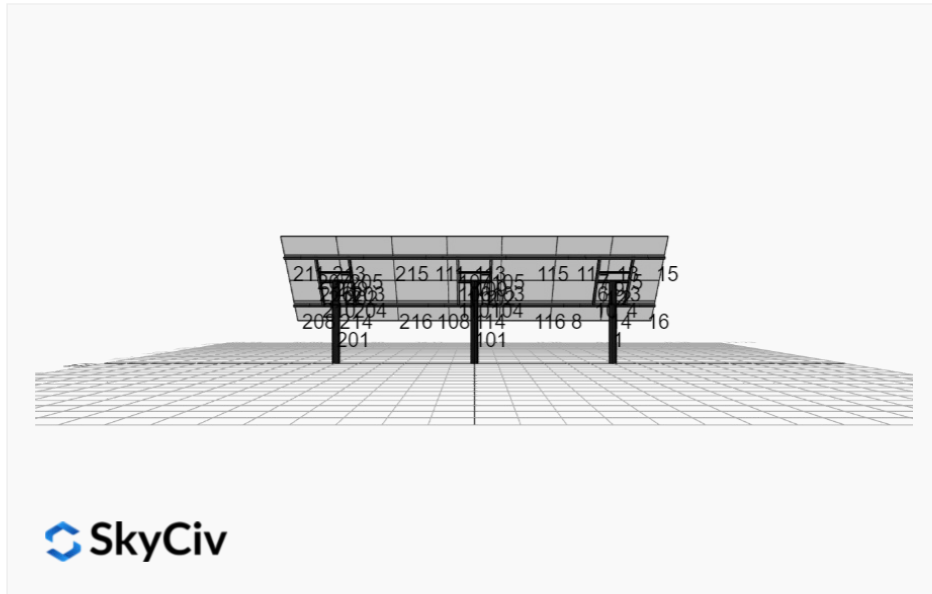
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

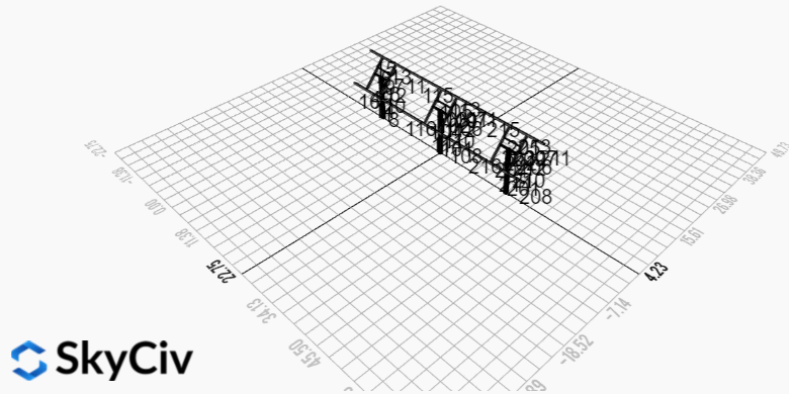
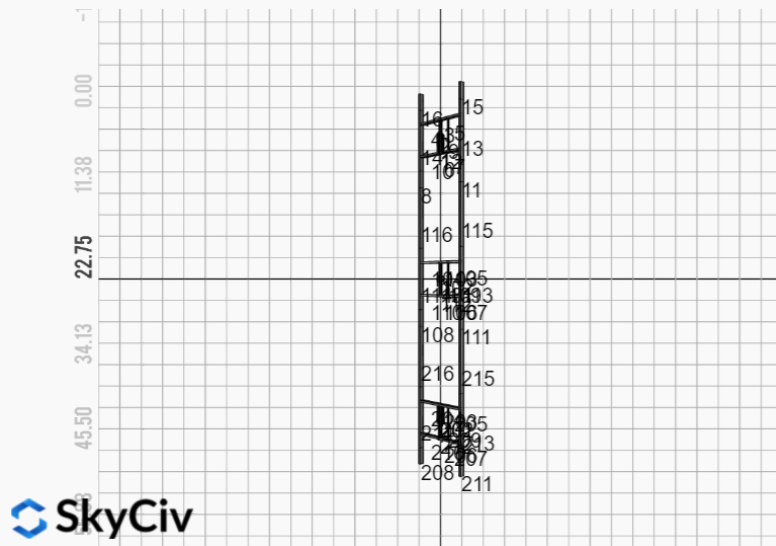
## AutoDesigner Input

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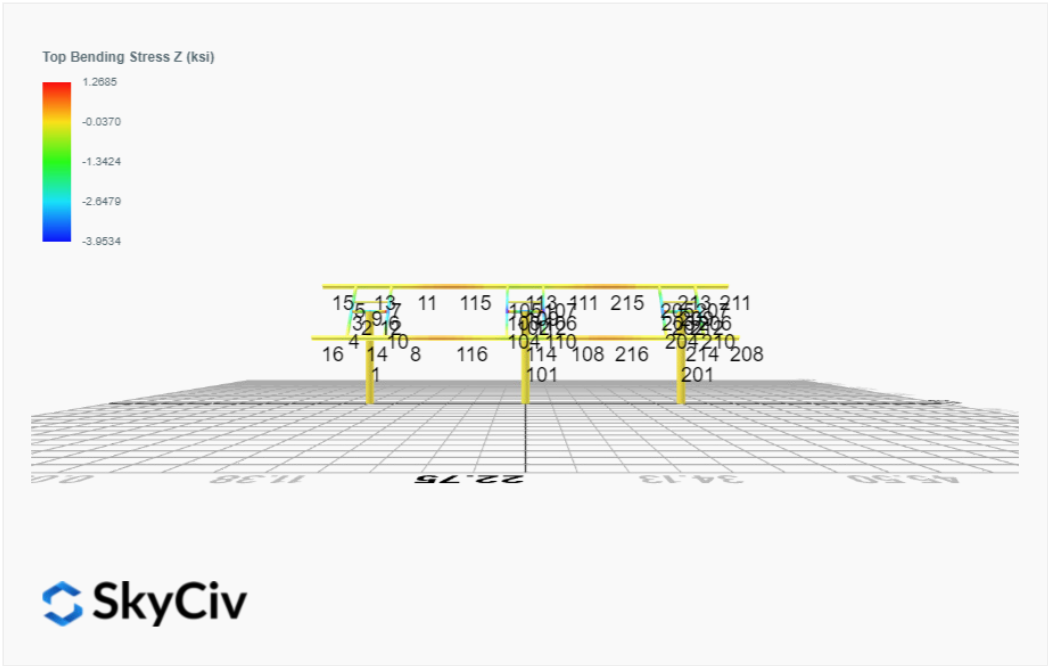
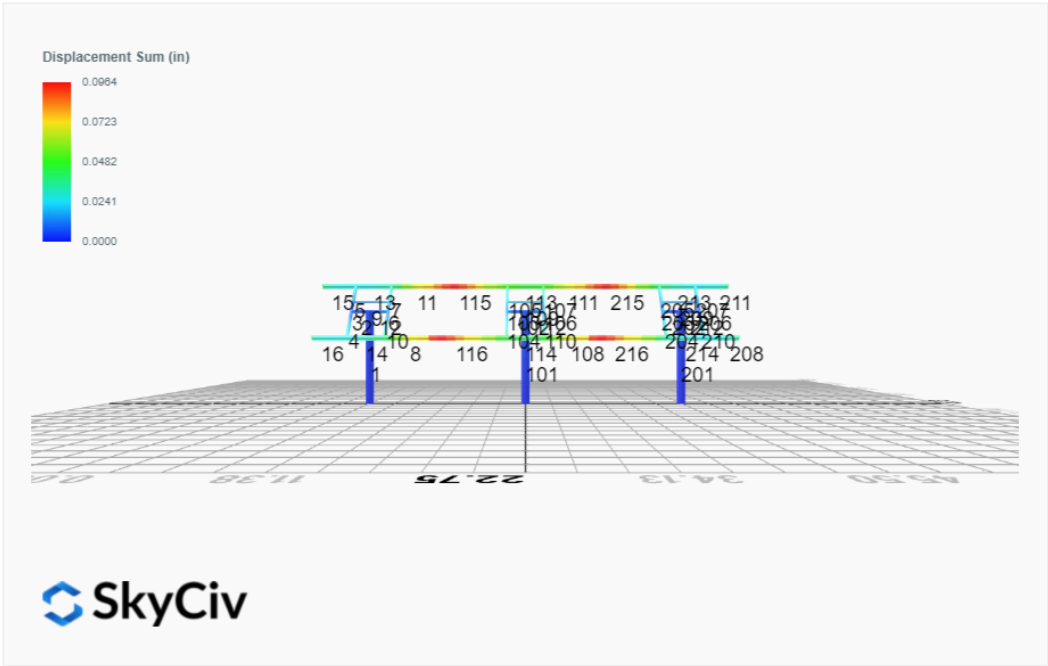
## Design Notes:

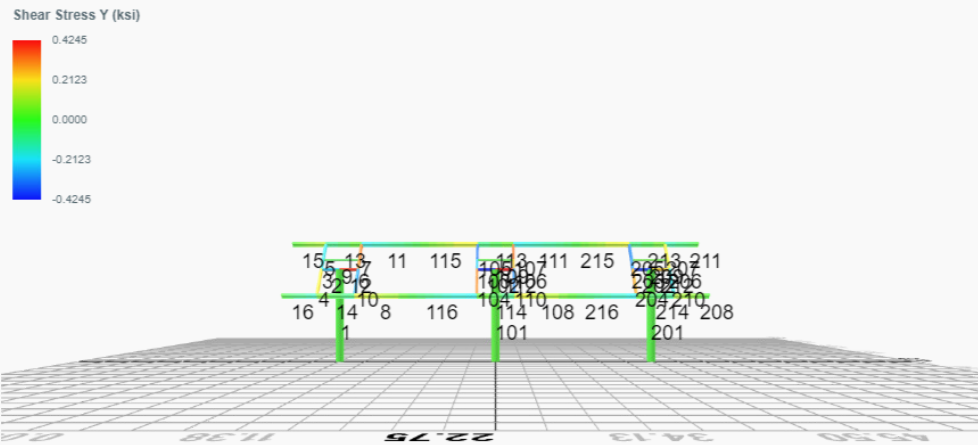
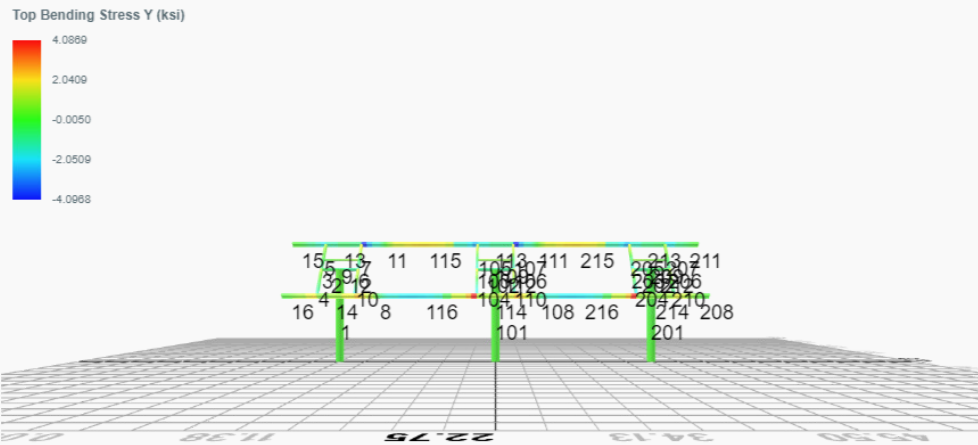
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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

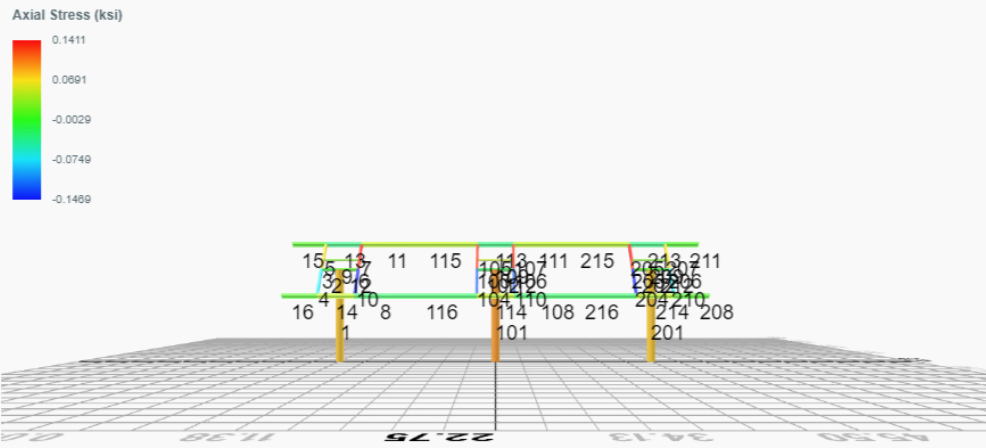




FEM Results (Envelope Worst Case for each member)









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   | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 2. D + L   | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 3. D + (S or Lr or R)  | 0.0244  | 2.7353  | 0.0764  | 0.1489  | -0.0683 | -0.2180  |
| ULS: 3. D + (S or Lr or R)  | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0214  | 2.4728  | 0.0672  | 0.1309  | -0.0600 | -0.1902  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 5b. D + 0.7E   | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S   | 0.0214  | 2.4728  | 0.0672  | 0.1309  | -0.0600 | -0.1902  |
| ULS: 8. 0.6D + 0.7E   | 0.0076  | 1.0112  | 0.0237  | 0.0462  | -0.0211 | -0.0640  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -1.7123 | 3.1204  | 0.1063  | 0.1676  | -0.5757 | 17.3146  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 1.7373  | 0.2503  | -0.0268 | -0.0133 | 0.5035  | -17.4384 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.2722 | 3.5491  | 0.1172  | 0.1989  | -0.4654 | 12.8758  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0214  | 2.4728  | 0.0672  | 0.1309  | -0.0600 | -0.1902  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3149  | 1.3966  | 0.0174  | 0.0632  | 0.3440  | -13.1890 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0214  | 2.4728  | 0.0672  | 0.1309  | -0.0600 | -0.1902  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.2810 | 2.7616  | 0.0896  | 0.1449  | -0.4406 | 12.9593  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3061  | 0.6091  | -0.0102 | 0.0092  | 0.3688  | -13.1055 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0126  | 1.6853  | 0.0396  | 0.0770  | -0.0351 | -0.1067  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -1.7173 | 2.4463  | 0.0904  | 0.1368  | -0.5616 | 17.3573  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | 0.0076  | 1.0112  | 0.0237  | 0.0462  | -0.0211 | -0.0640  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 1.7322  | -0.4238 | -0.0427 | -0.0441 | 0.5175  | -17.3957 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 0.0076  | 1.0112  | 0.0237  | 0.0462  | -0.0211 | -0.0640  |

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            | 4.9392              |
| Shear X          | -2.8956             |
| Shear Z          | 0.1773              |
| Moment X         | 0.2841              |
| Moment Y (Twist) | 0.9608              |
| Moment Z         | 29.1658             |

Worst Case Reactions ASD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 3.5491              |
| Shear X          | -1.7373             |
| Shear Z          | 0.1172              |
| Moment X         | 0.1989              |
| Moment Y (Twist) | 0.5757              |
| Moment Z         | 17.4384             |

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                              | -0.0252 | 1.9410 | 0.0000 | 0.0000 | 0.0000 | 0.2587 |
| ULS: 2. D + L                          | -0.0252 | 1.9410 | 0.0000 | 0.0000 | 0.0000 | 0.2587 |
| ULS: 3. D + (S or Lr or R)             | -0.0488 | 3.2287 | 0.0000 | 0.0000 | 0.0000 | 0.4886 |
| ULS: 3. D + (S or Lr or R)             | -0.0252 | 1.9410 | 0.0000 | 0.0000 | 0.0000 | 0.2587 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0429 | 2.9067 | 0.0000 | 0.0000 | 0.0000 | 0.4311 |

| Name  | Fx      | Fy      | Fz     | Mx     | My     | Mz       |
|---|---------|---------|--------|--------|--------|----------|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)  | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 5b. D + 0.7E   | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S   | -0.0429 | 2.9067  | 0.0000 | 0.0000 | 0.0000 | 0.4311   |
| ULS: 8. 0.6D + 0.7E   | -0.0151 | 1.1646  | 0.0000 | 0.0000 | 0.0000 | 0.1552   |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -2.1613 | 3.7579  | 0.0000 | 0.0000 | 0.0000 | 21.6697  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 2.1113  | 0.1238  | 0.0000 | 0.0000 | 0.0000 | -21.0243 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.6450 | 4.2695  | 0.0000 | 0.0000 | 0.0000 | 16.4893  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0429 | 2.9067  | 0.0000 | 0.0000 | 0.0000 | 0.4311   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5595  | 1.5439  | 0.0000 | 0.0000 | 0.0000 | -15.5311 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0429 | 2.9067  | 0.0000 | 0.0000 | 0.0000 | 0.4311   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.6273 | 3.3037  | 0.0000 | 0.0000 | 0.0000 | 16.3170  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.5772  | 0.5781  | 0.0000 | 0.0000 | 0.0000 | -15.7035 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0252 | 1.9410  | 0.0000 | 0.0000 | 0.0000 | 0.2587   |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -2.1513 | 2.9815  | 0.0000 | 0.0000 | 0.0000 | 21.5662  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -0.0151 | 1.1646  | 0.0000 | 0.0000 | 0.0000 | 0.1552   |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 2.1214  | -0.6525 | 0.0000 | 0.0000 | 0.0000 | -21.1278 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | -0.0151 | 1.1646  | 0.0000 | 0.0000 | 0.0000 | 0.1552   |

### 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            | 6.0012              |
| Shear X          | -3.6018             |
| Shear Z          | -0.0000             |
| Moment X         | 0.0001              |
| Moment Y (Twist) | 0.0001              |
| Moment Z         | 36.2533             |

### 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            | 4.2695              |
| Shear X          | -2.1613             |
| Shear Z          | 0.0000              |
| Moment X         | 0.0000              |
| Moment Y (Twist) | 0.0000              |
| Moment Z         | 21.6697             |

## 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                                    | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 2. D + L                                | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 3. D + (S or Lr or R)                   | 0.0244  | 2.7353 | -0.0764 | -0.1489 | 0.0683  | -0.2180  |
| ULS: 3. D + (S or Lr or R)                   | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | 0.0214  | 2.4728 | -0.0672 | -0.1309 | 0.0600  | -0.1902  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 5b. D + 0.7E                            | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S      | 0.0214  | 2.4728 | -0.0672 | -0.1309 | 0.0600  | -0.1902  |
| ULS: 8. 0.6D + 0.7E                          | 0.0076  | 1.0112 | -0.0237 | -0.0462 | 0.0211  | -0.0640  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.7123 | 3.1204 | -0.1063 | -0.1676 | 0.5757  | 17.3146  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only    | 1.7373  | 0.2503 | 0.0268  | 0.0133  | -0.5035 | -17.4384 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only    | 0.0126  | 1.6853 | -0.0396 | -0.0769 | 0.0351  | -0.1066  |

| 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 | -1.2722 | 3.5491  | -0.1172 | -0.1989 | 0.4654  | 12.8758  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0214  | 2.4728  | -0.0672 | -0.1309 | 0.0600  | -0.1902  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3149  | 1.3966  | -0.0174 | -0.0632 | -0.3440 | -13.1890 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0214  | 2.4728  | -0.0672 | -0.1309 | 0.0600  | -0.1902  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.2810 | 2.7616  | -0.0896 | -0.1449 | 0.4406  | 12.9593  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0126  | 1.6853  | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3061  | 0.6091  | 0.0102  | -0.0092 | -0.3688 | -13.1054 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0126  | 1.6853  | -0.0396 | -0.0769 | 0.0351  | -0.1066  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -1.7173 | 2.4463  | -0.0904 | -0.1368 | 0.5616  | 17.3573  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | 0.0076  | 1.0112  | -0.0237 | -0.0462 | 0.0211  | -0.0640  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 1.7322  | -0.4238 | 0.0427  | 0.0441  | -0.5175 | -17.3957 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 0.0076  | 1.0112  | -0.0237 | -0.0462 | 0.0211  | -0.0640  |

### 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            | 4.9392              |
| Shear X          | -2.8956             |
| Shear Z          | -0.1773             |
| Moment X         | -0.2840             |
| Moment Y (Twist) | 0.9610              |
| Moment Z         | 29.1660             |

### Worst Case Reactions ASD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 3.5491              |
| Shear X          | -1.7373             |
| Shear Z          | -0.1172             |
| Moment X         | -0.1989             |
| Moment Y (Twist) | 0.5757              |
| Moment Z         | 17.4384             |

Project Details

Design Code: AISC 360-16 LRFD  
Provision: LRFD  
Country: United States  
  
User Name: sales@mtsolar.us  
Unit System: imperial



Design Input Information

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

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

| Section Dimensions |                  |        |            |            |            |            |            |        |
|--------------------|------------------|--------|------------|------------|------------|------------|------------|--------|
|                    |                  |        |            |            |            |            |            |        |
| ID                 | Name             | d (in) | $t_w$ (in) |            |            |            |            |        |
| 1                  | 2in Pipe Sch 40  | 2.38   | 0.15       |            |            |            |            |        |
| 4                  | 4in Pipe Sch 40  | 4.50   | 0.24       |            |            |            |            |        |
| 11                 | 10in Pipe Sch 40 | 10.75  | 0.36       |            |            |            |            |        |
|                    |                  |        |            |            |            |            |            |        |
| ID                 | Name             | d (in) | b (in)     | $t_w$ (in) | $t_b$ (in) | r (in)     |            |        |
| 15                 | HSS5x3x1/8       | 5.00   | 3.00       | 0.12       | 0.12       | 0.12       |            |        |
|                    |                  |        |            |            |            |            |            |        |
| ID                 | Name             | d (in) | $t_w$ (in) | $b_t$ (in) | $b_b$ (in) | $t_t$ (in) | $t_b$ (in) | r (in) |
| 18                 | W6x9             | 5.90   | 0.17       | 3.94       | 3.94       | 0.21       | 0.21       | 0.25   |

| Section Properties |      |                      |                      |                             |                             |                          |                             |                             |
|--------------------|------|----------------------|----------------------|-----------------------------|-----------------------------|--------------------------|-----------------------------|-----------------------------|
| ID                 | Name | A (in <sup>2</sup> ) | J (in <sup>4</sup> ) | $I_{yp}$ (in <sup>4</sup> ) | $I_{zp}$ (in <sup>4</sup> ) | $I_w$ (in <sup>6</sup> ) | $S_{yp}$ (in <sup>3</sup> ) | $S_{zp}$ (in <sup>3</sup> ) |

|    |                  |       |        |        |        |       |       |       |
|----|------------------|-------|--------|--------|--------|-------|-------|-------|
| 1  | 2in Pipe Sch 40  | 1.07  | 1.33   | 0.67   | 0.67   | 0.00  | 0.76  | 0.76  |
| 4  | 4in Pipe Sch 40  | 3.17  | 14.47  | 7.23   | 7.23   | 0.00  | 4.31  | 4.31  |
| 11 | 10in Pipe Sch 40 | 11.91 | 321.47 | 160.73 | 160.73 | 0.00  | 39.38 | 39.38 |
| 15 | HSS5x3x1/8       | 1.77  | 6.02   | 2.75   | 6.03   | 0.51  | 2.07  | 2.93  |
| 18 | W6x9             | 2.68  | 0.04   | 2.20   | 16.40  | 17.70 | 1.72  | 6.23  |

| Member Properties |            |                       |                       |                     |   |      |      |     |  |
|-------------------|------------|-----------------------|-----------------------|---------------------|---|------|------|-----|--|
| Member ID         | Section ID | K <sub>z</sub> L (ft) | K <sub>y</sub> L (ft) | L <sub>b</sub> (ft) | C <sub>b</sub>  | LS T | LS C | L D |  |
| 1                 | 11         | 21.09                 | 21.09                 | 10.04               | -   | 300  | 200  | 1   |  |
| 2                 | 4          | 1.30                  | 1.30                  | 2.00                | -   | 300  | 200  | 1   |  |
| 3                 | 15         | 0.92                  | 0.92                  | 1.42                | 1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.18,1.18,1.28,1.18,1.18,1.18,1.16,1.18,1.17,1.18,1.17,1.18           | 300  | 200  | 1   |  |
| 4                 | 15         | 2.44                  | 2.44                  | 3.75                | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.86,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69 | 300  | 200  | 1   |  |
| 5                 | 15         | 1.52                  | 1.52                  | 2.33                | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.80,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 6                 | 15         | 0.92                  | 0.92                  | 1.42                | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.31,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19           | 300  | 200  | 1   |  |
| 7                 | 15         | 1.52                  | 1.52                  | 2.33                | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.93,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 8                 | 18         | 1.33                  | 1.33                  | 2.05                | 1.34,1.34,1.34,1.34,1.34,1.34,1.33,1.34,1.33,1.34,1.33,1.34,1.33,1.34,1.34,1.34,1.46,1.34,1.33,1.34,1.33,1.34,1.33,1.34,1.33,1.34 | 300  | 200  | 1   |  |
| 9                 | 1          | 2.60                  | 2.60                  | 4.00                | -   | 300  | 200  | 1   |  |
| 10                | 15         | 2.44                  | 2.44                  | 3.75                | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.87,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 11                | 18         | 1.33                  | 1.33                  | 2.05                | 1.35,1.35,1.35,1.35,1.35,1.35,1.36,1.35,1.38,1.35,1.36,1.35,1.37,1.35,1.36,1.35,1.04,1.35,1.36,1.35,1.38,1.35,1.37,1.35,1.37,1.35 | 300  | 200  | 1   |  |
| 12                | 4          | 2.00                  | 1.30                  | 2.00                | -   | 300  | 200  | 1   |  |
| 13                | 18         | 4.88                  | 4.00                  | 7.50                | 1.17,1.17,1.16,1.17,1.17,1.16,1.16,1.17,1.15,1.17,1.16,1.16,1.16,1.16,1.16,1.17,1.99,1.17,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16 | 300  | 200  | 1   |  |
| 14                | 18         | 4.88                  | 4.00                  | 7.50                | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.16,1.16,1.16,1.16           | 300  | 200  | 1   |  |
| 15                | 18         | 4.20                  | 4.20                  | 2.00                | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33           | 300  | 200  | 1   |  |
| 16                | 18         | 4.20                  | 4.20                  | 2.00                | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33           | 300  | 200  | 1   |  |
| 101               | 11         | 21.09                 | 21.09                 | 10.04               | -   | 300  | 200  | 1   |  |
| 102               | 4          | 1.30                  | 1.30                  | 2.00                | -   | 300  | 200  | 1   |  |
| 103               | 15         | 0.92                  | 0.92                  | 1.42                | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.23,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19      | 300  | 200  | 1   |  |
| 104               | 15         | 2.44                  | 2.44                  | 3.75                | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.82,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 105               | 15         | 1.52                  | 1.52                  | 2.33                | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.74,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 106               | 15         | 0.92                  | 0.92                  | 1.42                | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.23,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19 | 300  | 200  | 1   |  |
| 107               | 15         | 1.52                  | 1.52                  | 2.33                | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.74,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 108               | 18         | 1.33                  | 1.33                  | 2.05                | 1.65,1.65,1.65,1.66,1.65,1.65,1.62,1.65,1.60,1.65,1.62,1.65,1.60,1.65,1.63,1.66,1.88,1.66,1.63,1.65,1.59,1.65,1.62,1.65,1.61,1.65 | 300  | 200  | 1   |  |
| 109               | 1          | 2.60                  | 2.60                  | 4.00                | -   | 300  | 200  | 1   |  |
| 110               | 15         | 2.44                  | 2.44                  | 3.75                | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.82,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300  | 200  | 1   |  |
| 111               | 18         | 1.33                  | 1.33                  | 2.05                | 1.61,1.61,1.61,1.61,1.61,1.61,1.51,1.61,1.44,1.61,1.50,1.61,1.45,1.61,1.54,1.61,1.25,1.61,1.52,1.61,1.40,1.61,1.50,1.61,1.46,1.61 | 300  | 200  | 1   |  |
| 112               | 4          | 1.30                  | 1.30                  | 2.00                | -   | 300  | 200  | 1   |  |

|     |    |           |           |           |  |         |         |   |
|-----|----|-----------|-----------|-----------|--|---------|---------|---|
| 113 | 18 | 4.88      | 4.00      | 7.5<br>0  | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.01,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06      | 30<br>0 | 20<br>0 | 1 |
| 114 | 18 | 4.88      | 4.00      | 7.5<br>0  | 1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.03,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05      | 30<br>0 | 20<br>0 | 1 |
| 115 | 18 | 4.84      | 4.84      | 7.4<br>5  | 1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.14,1.11,1.14,1.12,1.14,1.12,1.14,1.13,1.14,2.44,1.14,1.13,1.14,1.11,1.14,1.12,1.14,1.12,1.14      | 30<br>0 | 20<br>0 | 1 |
| 116 | 18 | 4.84      | 4.84      | 7.4<br>5  | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.70,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14           | 30<br>0 | 20<br>0 | 1 |
| 201 | 11 | 21.0<br>9 | 21.0<br>9 | 10.<br>04 | -  | 30<br>0 | 20<br>0 | 1 |
| 202 | 4  | 2.00      | 1.30      | 2.0<br>0  | -  | 30<br>0 | 20<br>0 | 1 |
| 203 | 15 | 0.92      | 0.92      | 1.4<br>2  | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.31,1.19,1.18,1.19,1.11,1.19,1.18,1.19,1.18,1.19      | 30<br>0 | 20<br>0 | 1 |
| 204 | 15 | 2.44      | 2.44      | 3.7<br>5  | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.87,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68      | 30<br>0 | 20<br>0 | 1 |
| 205 | 15 | 1.52      | 1.52      | 2.3<br>3  | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.93,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68      | 30<br>0 | 20<br>0 | 1 |
| 206 | 15 | 0.92      | 0.92      | 1.4<br>2  | 1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.18,1.18,1.28,1.18,1.18,1.18,1.11,1.18,1.17,1.18,1.17,1.18      | 30<br>0 | 20<br>0 | 1 |
| 207 | 15 | 1.52      | 1.52      | 2.3<br>3  | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.80,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68      | 30<br>0 | 20<br>0 | 1 |
| 208 | 18 | 4.20      | 4.20      | 2.0<br>0  | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33           | 30<br>0 | 20<br>0 | 1 |
| 209 | 1  | 2.60      | 2.60      | 4.0<br>0  | -  | 30<br>0 | 20<br>0 | 1 |
| 210 | 15 | 2.44      | 2.44      | 3.7<br>5  | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.86,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69      | 30<br>0 | 20<br>0 | 1 |
| 211 | 18 | 4.20      | 4.20      | 2.0<br>0  | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33           | 30<br>0 | 20<br>0 | 1 |
| 212 | 4  | 1.30      | 1.30      | 2.0<br>0  | -  | 30<br>0 | 20<br>0 | 1 |
| 213 | 18 | 4.88      | 4.00      | 7.5<br>0  | 1.16,1.17,1.16,1.17,1.17,1.16,1.16,1.17,1.15,1.17,1.16,1.16,1.16,1.16,1.16,1.17,2.00,1.17,1.16,1.16,1.11,1.16,1.16,1.16,1.16,1.16      | 30<br>0 | 20<br>0 | 1 |
| 214 | 18 | 4.88      | 4.00      | 7.5<br>0  | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.11,1.16,1.16,1.16,1.16           | 30<br>0 | 20<br>0 | 1 |
| 215 | 18 | 4.84      | 4.84      | 7.4<br>5  | 1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.10,1.09,1.09,2.51,1.09,1.10,1.09,1.11,1.09,1.10,1.09,1.10,1.09 | 30<br>0 | 20<br>0 | 1 |
| 216 | 18 | 4.84      | 4.84      | 7.4<br>5  | 1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.13,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09           | 30<br>0 | 20<br>0 | 1 |

## Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|-----------|--------------------|--------------------|------------------------|------------------------|-----------------------|-----------------------|
| 1         | 535.87             | 378.77             | 147.68                 | 147.68                 | 160.76                | 160.76                |
| 2         | 142.83             | 141.72             | 16.17                  | 16.17                  | 42.85                 | 42.85                 |
| 3         | 79.65              | 74.02              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 4         | 79.65              | 72.01              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 5         | 79.65              | 73.44              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 6         | 79.65              | 74.02              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 7         | 79.65              | 73.44              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 8         | 120.60             | 115.40             | 23.36                  | 6.45                   | 30.09                 | 45.74                 |
| 9         | 48.35              | 43.11              | 2.85                   | 2.85                   | 14.51                 | 14.51                 |
| 10        | 79.65              | 72.01              | 10.99                  | 6.26                   | 29.14                 | 16.61                 |
| 11        | 120.60             | 115.40             | 23.36                  | 6.45                   | 30.09                 | 45.74                 |
| 12        | 142.83             | 140.22             | 16.17                  | 16.17                  | 42.85                 | 42.85                 |
| 13        | 120.60             | 84.03              | 20.28                  | 6.45                   | 30.09                 | 45.74                 |
| 14        | 120.60             | 84.03              | 20.35                  | 6.45                   | 30.09                 | 45.74                 |
| 15        | 120.60             | 96.18              | 23.36                  | 6.45                   | 30.09                 | 45.74                 |
| 16        | 120.60             | 96.18              | 23.36                  | 6.45                   | 30.09                 | 45.74                 |

|     |        |        |        |        |        |        |
|-----|--------|--------|--------|--------|--------|--------|
| 101 | 555.87 | 578.77 | 147.08 | 147.08 | 100.70 | 100.70 |
| 102 | 142.83 | 141.72 | 16.17  | 16.17  | 42.85  | 42.85  |
| 103 | 79.65  | 74.02  | 10.99  | 6.26   | 29.14  | 16.61  |
| 104 | 79.65  | 72.01  | 10.99  | 6.26   | 29.14  | 16.61  |
| 105 | 79.65  | 73.44  | 10.99  | 6.26   | 29.14  | 16.61  |
| 106 | 79.65  | 74.02  | 10.99  | 6.26   | 29.14  | 16.61  |
| 107 | 79.65  | 73.44  | 10.99  | 6.26   | 29.14  | 16.61  |
| 108 | 120.60 | 115.40 | 23.36  | 6.45   | 30.09  | 45.74  |
| 109 | 48.35  | 43.11  | 2.85   | 2.85   | 14.51  | 14.51  |
| 110 | 79.65  | 72.01  | 10.99  | 6.26   | 29.14  | 16.61  |
| 111 | 120.60 | 115.40 | 23.36  | 6.45   | 30.09  | 45.74  |
| 112 | 142.83 | 141.72 | 16.17  | 16.17  | 42.85  | 42.85  |
| 113 | 120.60 | 84.03  | 17.83  | 6.45   | 30.09  | 45.74  |
| 114 | 120.60 | 84.03  | 18.09  | 6.45   | 30.09  | 45.74  |
| 115 | 120.60 | 84.26  | 19.56  | 6.45   | 30.09  | 45.74  |
| 116 | 120.60 | 84.26  | 20.06  | 6.45   | 30.09  | 45.74  |
| 201 | 535.87 | 378.77 | 147.68 | 147.68 | 160.76 | 160.76 |
| 202 | 142.83 | 140.22 | 16.17  | 16.17  | 42.85  | 42.85  |
| 203 | 79.65  | 74.02  | 10.99  | 6.26   | 29.14  | 16.61  |
| 204 | 79.65  | 72.01  | 10.99  | 6.26   | 29.14  | 16.61  |
| 205 | 79.65  | 73.44  | 10.99  | 6.26   | 29.14  | 16.61  |
| 206 | 79.65  | 74.02  | 10.99  | 6.26   | 29.14  | 16.61  |
| 207 | 79.65  | 73.44  | 10.99  | 6.26   | 29.14  | 16.61  |
| 208 | 120.60 | 96.18  | 23.36  | 6.45   | 30.09  | 45.74  |
| 209 | 48.35  | 43.11  | 2.85   | 2.85   | 14.51  | 14.51  |
| 210 | 79.65  | 72.01  | 10.99  | 6.26   | 29.14  | 16.61  |
| 211 | 120.60 | 96.18  | 23.36  | 6.45   | 30.09  | 45.74  |
| 212 | 142.83 | 141.72 | 16.17  | 16.17  | 42.85  | 42.85  |
| 213 | 120.60 | 84.03  | 20.28  | 6.45   | 30.09  | 45.74  |
| 214 | 120.60 | 84.03  | 20.35  | 6.45   | 30.09  | 45.74  |
| 215 | 120.60 | 84.26  | 19.27  | 6.45   | 30.09  | 45.74  |
| 216 | 120.60 | 84.26  | 19.21  | 6.45   | 30.09  | 45.74  |

## 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         | 0.013 | 0.197          | 0.010          | 0.018          | 0.001          | 0.204                               | #13      | 0.344        | Not Required | Pass   |
| 2         | 0.001 | 0.177          | 0.143          | 0.044          | 0.030          | 0.321                               | #13      | 0.052        | Not Required | Pass   |
| 3         | 0.007 | 0.373          | 0.049          | 0.037          | 0.009          | 0.401                               | #13      | 0.044        | Not Required | Pass   |
| 4         | 0.006 | 0.370          | 0.071          | 0.038          | 0.014          | 0.424                               | #13      | 0.078        | Not Required | Pass   |
| 5         | 0.006 | 0.231          | 0.058          | 0.037          | 0.011          | 0.233                               | #13      | 0.073        | Not Required | Pass   |
| 6         | 0.010 | 0.484          | 0.102          | 0.050          | 0.023          | 0.554                               | #13      | 0.044        | Not Required | Pass   |
| 7         | 0.010 | 0.300          | 0.125          | 0.048          | 0.024          | 0.319                               | #13      | 0.073        | Not Required | Pass   |
| 8         | 0.001 | 0.073          | 0.057          | 0.026          | 0.009          | 0.113                               | #21      | 0.088        | Not Required | Pass   |
| 9         | 0.001 | 0.029          | 0.056          | 0.002          | 0.002          | 0.085                               | #13      | 0.198        | Not Required | Pass   |
| 10        | 0.010 | 0.473          | 0.121          | 0.048          | 0.022          | 0.514                               | #13      | 0.078        | Not Required | Pass   |
| 11        | 0.002 | 0.072          | 0.055          | 0.027          | 0.009          | 0.112                               | #21      | 0.088        | Not Required | Pass   |
| 12        | 0.001 | 0.270          | 0.202          | 0.060          | 0.040          | 0.473                               | #13      | 0.079        | Not Required | Pass   |
| 13        | 0.003 | 0.077          | 0.173          | 0.037          | 0.012          | 0.215                               | #21      | 0.265        | Not Required | Pass   |
| 14        | 0.003 | 0.077          | 0.172          | 0.036          | 0.012          | 0.207                               | #21      | 0.177        | Not Required | Pass   |
| 15        | 0.000 | 0.015          | 0.026          | 0.012          | 0.004          | 0.037                               | #21      | Not Required | Not Required | Pass   |

|     |       |       |       |       |       |       |     |              |              |      |
|-----|-------|-------|-------|-------|-------|-------|-----|--------------|--------------|------|
| 16  | 0.000 | 0.015 | 0.026 | 0.012 | 0.004 | 0.037 | #21 | Not Required | Not Required | Pass |
| 101 | 0.016 | 0.245 | 0.000 | 0.022 | 0.000 | 0.253 | #13 | 0.344        | Not Required | Pass |
| 102 | 0.001 | 0.279 | 0.219 | 0.064 | 0.042 | 0.498 | #13 | 0.052        | Not Required | Pass |
| 103 | 0.010 | 0.529 | 0.082 | 0.053 | 0.017 | 0.584 | #13 | 0.044        | Not Required | Pass |
| 104 | 0.009 | 0.536 | 0.124 | 0.054 | 0.022 | 0.601 | #13 | 0.078        | Not Required | Pass |
| 105 | 0.010 | 0.328 | 0.127 | 0.053 | 0.024 | 0.347 | #13 | 0.073        | Not Required | Pass |
| 106 | 0.010 | 0.529 | 0.082 | 0.053 | 0.017 | 0.584 | #13 | 0.044        | Not Required | Pass |
| 107 | 0.010 | 0.328 | 0.127 | 0.053 | 0.024 | 0.347 | #13 | 0.073        | Not Required | Pass |
| 108 | 0.001 | 0.059 | 0.055 | 0.030 | 0.009 | 0.097 | #21 | 0.088        | Not Required | Pass |
| 109 | 0.003 | 0.032 | 0.043 | 0.001 | 0.000 | 0.076 | #13 | 0.198        | Not Required | Pass |
| 110 | 0.009 | 0.536 | 0.124 | 0.054 | 0.022 | 0.601 | #13 | 0.078        | Not Required | Pass |
| 111 | 0.002 | 0.064 | 0.055 | 0.029 | 0.009 | 0.101 | #21 | 0.088        | Not Required | Pass |
| 112 | 0.001 | 0.279 | 0.219 | 0.064 | 0.042 | 0.498 | #13 | 0.052        | Not Required | Pass |
| 113 | 0.003 | 0.105 | 0.175 | 0.039 | 0.012 | 0.250 | #21 | 0.265        | Not Required | Pass |
| 114 | 0.003 | 0.120 | 0.175 | 0.040 | 0.012 | 0.257 | #21 | 0.265        | Not Required | Pass |
| 115 | 0.003 | 0.111 | 0.101 | 0.029 | 0.009 | 0.187 | #21 | 0.321        | Not Required | Pass |
| 116 | 0.001 | 0.108 | 0.101 | 0.030 | 0.009 | 0.184 | #21 | 0.321        | Not Required | Pass |
| 201 | 0.013 | 0.197 | 0.010 | 0.018 | 0.001 | 0.204 | #13 | 0.344        | Not Required | Pass |
| 202 | 0.001 | 0.270 | 0.202 | 0.060 | 0.040 | 0.473 | #13 | 0.079        | Not Required | Pass |
| 203 | 0.010 | 0.484 | 0.102 | 0.050 | 0.023 | 0.554 | #13 | 0.044        | Not Required | Pass |
| 204 | 0.010 | 0.473 | 0.121 | 0.048 | 0.022 | 0.514 | #13 | 0.078        | Not Required | Pass |
| 205 | 0.010 | 0.300 | 0.125 | 0.048 | 0.024 | 0.319 | #13 | 0.073        | Not Required | Pass |
| 206 | 0.007 | 0.373 | 0.049 | 0.037 | 0.009 | 0.401 | #13 | 0.044        | Not Required | Pass |
| 207 | 0.006 | 0.231 | 0.058 | 0.037 | 0.011 | 0.233 | #13 | 0.073        | Not Required | Pass |
| 208 | 0.000 | 0.015 | 0.026 | 0.012 | 0.004 | 0.037 | #21 | Not Required | Not Required | Pass |
| 209 | 0.001 | 0.029 | 0.056 | 0.002 | 0.002 | 0.085 | #13 | 0.198        | Not Required | Pass |
| 210 | 0.006 | 0.370 | 0.071 | 0.038 | 0.014 | 0.424 | #13 | 0.078        | Not Required | Pass |
| 211 | 0.000 | 0.015 | 0.026 | 0.012 | 0.004 | 0.037 | #21 | Not Required | Not Required | Pass |
| 212 | 0.001 | 0.177 | 0.143 | 0.044 | 0.030 | 0.321 | #13 | 0.052        | Not Required | Pass |
| 213 | 0.003 | 0.077 | 0.173 | 0.037 | 0.012 | 0.215 | #21 | 0.177        | Not Required | Pass |
| 214 | 0.003 | 0.077 | 0.172 | 0.036 | 0.012 | 0.207 | #21 | 0.265        | Not Required | Pass |
| 215 | 0.003 | 0.116 | 0.101 | 0.027 | 0.009 | 0.190 | #21 | 0.321        | Not Required | Pass |
| 216 | 0.001 | 0.114 | 0.101 | 0.026 | 0.009 | 0.189 | #21 | 0.321        | Not Required | Pass |

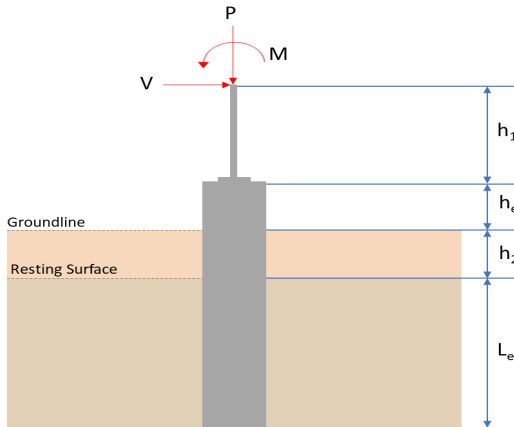
## Definitions

|          |   |
|----------|---|
| $\Phi_t$ | 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                                  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
|----------------|---|--|--|--|--|---|---|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|-------|-------|------------|-------|-------|------------|--------|--------|--|--|
|                | <div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>  |  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
|                | <div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 5.5 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa)<br/>(psf)</th><th>Allowable Lateral Pressure (R)<br/>(psf/ft)</th></tr><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></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>3.549</td><td>4.939</td></tr><tr><td>Vx (kip)</td><td>-1.737</td><td>-2.896</td></tr><tr><td>Vz (kip)</td><td>0.117</td><td>0.177</td></tr><tr><td>Mx (kipft)</td><td>0.199</td><td>0.284</td></tr><tr><td>Mz (kipft)</td><td>17.438</td><td>29.166</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div> | Layer                                    | Label                                      | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 3.549 | 4.939 | Vx (kip) | -1.737 | -2.896 | Vz (kip) | 0.117 | 0.177 | Mx (kipft) | 0.199 | 0.284 | Mz (kipft) | 17.438 | 29.166 | <div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div><math display="block">H = h_1 + h_2 + h_e</math></div> <div><math display="block">H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})</math></div> <div><math display="block">H = 0 \text{ ft}</math></div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div><math display="block">H_o = \frac{V_x}{1.57 \text{ } D}</math></div> <div><math display="block">H_o = \frac{(-1.737 \text{ kip})}{1.57 \times (48 \text{ in})}</math></div> <div><math display="block">H_o = -0.27659 \text{ kip/ft}</math></div> |  |
| Layer          | Label   | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| 1              | Sand, silty sand, clayey sand, silty gravel & clayey gravel   | 2000.000                                 | 150.000                                    |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Load Component | ASD   | LRFD                                     |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| P (kip)        | 3.549   | 4.939                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Vx (kip)       | -1.737  | -2.896                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Vz (kip)       | 0.117   | 0.177                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Mx (kipft)     | 0.199   | 0.284                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Mz (kipft)     | 17.438  | 29.166                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |

|  |   |   |
|--|---|---|
|  | <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(17.438 \text{ kipft}) + ((-1.737 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 2.7768 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left( 14.14 \times \frac{H_o \times L_x}{R} \right) - \left( 18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation:<br/> <math>L_{e,x} = 5.1509 \text{ ft}</math> - Required depth in x-direction,</p> <p><b>Considering z-direction:</b></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(0.117 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = 0.018631 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.199 \text{ kipft}) + ((0.117 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.031688 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_z^3 - \left( 14.14 \times \frac{H_o \times L_z}{R} \right) - \left( 18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation:<br/> <math>L_{e,z} = 1.6339 \text{ ft}</math> - Required depth in z-direction,</p> <p><b>Minimum embedded depth required:</b></p> <p><math>L_{e,req}</math> - Depth of pile required,</p> $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.1509 \text{ ft}), (1.6339 \text{ ft})]$ $L_{e,req} = 5.151 \text{ ft}$ <p><math>L_e</math> - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 5.5 \text{ ft}$ <p><b>Ratio</b> - Embedded depth</p> $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.151 \text{ ft})}{(5.5 \text{ ft})}$ $\text{Ratio} = 0.93655$ | <p>Status: <b>PASS</b><br/> Ratio: <b>0.940</b></p> |
|  | <p><b>End-bearing Capacity (ASD)</b></p> <p><math>A</math> - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p><math>q</math> - End-bearing pressure</p>  |   |

|          |  |  |
|----------|--|--|
|          | $q = \frac{P_v}{A}$ $q = \frac{(3.549 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.22181 \text{ kip/ft}^2$ <p><b>Check bearing capacity ratio:</b></p> <p>Ratio - Capacity</p> $\text{Ratio} = \frac{q}{q_a}$ $\text{Ratio} = \frac{(0.22181 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.11091$  | <p>Status: <b>PASS</b><br/>Ratio: <b>0.110</b></p> |
| Czerniak | <p><b>Lateral Soil Pressure (ASD):</b></p> <p><math>L/D</math> - Length to least lateral dimension ratio,</p> $L/D = \frac{L}{D}$ $L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$ $L/D = 1.375$ <p>Since <math>L/D \leq 10</math>,</p> <p>Pile is short.</p> <p><b>Considering x-direction:</b></p> <p><math>H_o = -0.27659 \text{ kip/ft}</math> - Lateral force per length of pile,<br/> <math>M_o = 2.7768 \text{ kipft/ft}</math> - Overturning moment per length of pile,<br/> <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (2.7768 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7768 \text{ kipft/ft})) + (4 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.7893 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (2.7768 \text{ kipft/ft})) + (3 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7768 \text{ kipft/ft})) + (2 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.20075 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (2.7768 \text{ kipft/ft})) + ((-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.79978 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.7893 \text{ ft})}{2}$ $p_a = 0.2842 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> |  |

|  |  |   |
|--|--|---|
|  | $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.20075 \text{ kip/ft}^2)}{(0.2842 \text{ kip/ft}^2)}$ $Ratio = 0.70637$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(0.79978 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $Ratio = 0.96944$   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.710</b></p> <p>Status: <b>PASS</b><br/>Ratio: <b>0.970</b></p> |
|  | <p><b>Considering z-direction:</b></p> <p><math>H_o = 0.018631 \text{ kip/ft}</math> - Lateral force per length of pile,<br/> <math>M_o = 0.031688 \text{ kipft/ft}</math> - Overturning moment per length of pile,<br/> <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.031688 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.018631 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.031688 \text{ kipft/ft})) + (4 \times (0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9798 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.031688 \text{ kipft/ft})) + (3 \times (0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.031688 \text{ kipft/ft})) + (2 \times (0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.015578 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.031688 \text{ kipft/ft})) + ((0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.032895 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9798 \text{ ft})}{2}$ $p_a = 0.29848 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.015578 \text{ kip/ft}^2)}{(0.29848 \text{ kip/ft}^2)}$ |   |

$$Ratio = 0.05219$$

Status: **PASS**  
Ratio: **0.050**

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

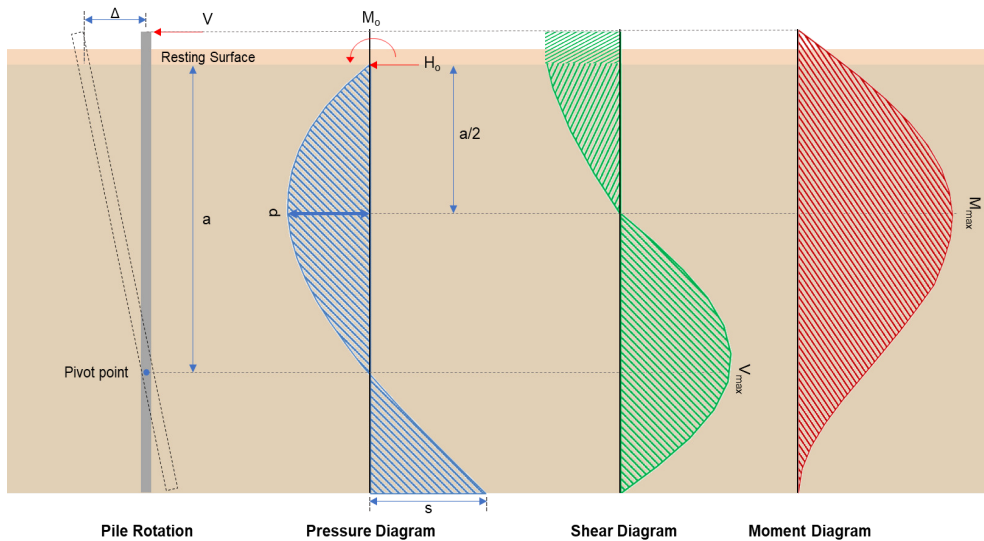
Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.032895 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.039872$$

Status: **PASS**  
Ratio: **0.040**



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-2.896 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.46115 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(29.166 \text{ kipft}) + ((-2.896 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6443 \text{ kipft/ft}$$

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

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

$$E = \frac{(4.6443 \text{ kipft/ft})}{(-0.46115 \text{ kip/ft})}$$

$$E = 10.071 \text{ ft}$$

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

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

$$a = \frac{(4 \times (4.6443 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.6443 \text{ kipft/ft})) + (4 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.6443 \text{ kipft/ft})) + (4 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft}))}{}$$

$$a = 3.789 \text{ ft}$$

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

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

$$V_{max} = ((-0.46115 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.789 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.789 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1938 \text{ kip}$$

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

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

$$M_{max} = ((-0.46115 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(10.071 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.789 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.789 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^3 \right] + \left[ \left( \frac{3 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.789 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 18.861 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.177 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.028185 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.284 \text{ kipft}) + ((0.177 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.045223 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.045223 \text{ kipft/ft})}{(0.028185 \text{ kip/ft})}$$

$$E = 1.6045 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.045223 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.028185 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.045223 \text{ kipft/ft})) + (4 \times (0.028185 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9855 \text{ ft}$$

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

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



$$V_{max} = ((0.028185 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9855 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9855 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.13394 \text{ kip}$$

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

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

$$M_{max} = ((0.028185 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(1.6045 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.31338 \text{ kipft}$$

#### 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,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

##### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = Min \left[ \frac{\left( \frac{(4.939 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2)) \right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.432 \text{ in}^2$$

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

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

$$A_{min} = Max [(-84.432 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|   |   |  |
|---|---|--|
| <p>25.2.3</p>                                   | <p><math>s_{rebar} = 0.96556</math></p> <p><math>s_{rebar}</math> - Minimum spacing of reinforcement,</p> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> <p>25.7.2.2 Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 <math>s_{ties}</math> - Maximum spacing of ties,</p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p><b>Summary:</b></p> <p>Main reinforcement: <b>14 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></p>   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.970</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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><math>Ratio</math> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(4.939 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0018462$   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.1.3</p> <p>22.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p><math>\lambda_s</math> - size effect modification factor</p> $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <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> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ |  |

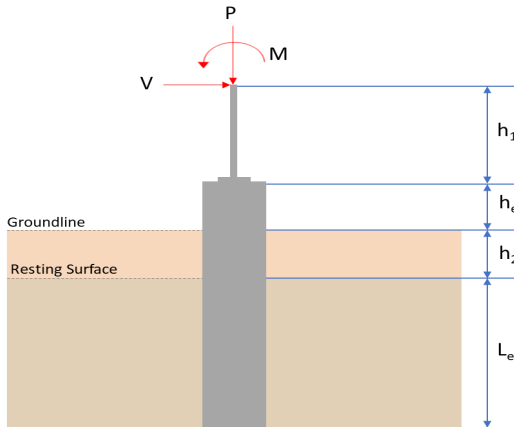
|               |  |   |  |
|---------------|--|---|--|
|               |  | $V_{c,max} = 296.21 \text{ kip}$  |  |
| 22.5.5.1.1(a) | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ , $P = 4.939 \text{ kip} \rightarrow 4939 \text{ lbf}$ ,<br>$V_{c,a}$ - Shear strength of concrete (a) | $V_{c,a} = \left[ 2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(4939 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 119.14 \text{ kip}$ |  |
| 22.5.5.1.2    | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,<br>$V_{c,b}$ - Shear strength of concrete (b)  | $V_{c,b} = \left[ 2 \lambda_s \sqrt{f'_{ck}} + (0.05 f'_{ck}) \right] b_w d$ $V_{c,b} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,b} = 348.89 \text{ kip}$                         |  |
|               | $V_c$ - Governing shear strength of concrete   | $V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (119.14 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 119.14 \text{ kip}$   |  |
| 22.5.1.2      | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,<br>$V_{s,a}$ - Shear strength of steel (a)   | $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$  |  |
|               | $A_v$ - Ties rebar area,   | $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$   |  |
| 22.5.8.5.3    | $V_{s,b}$ - Shear strength of steel (b)  | $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$   |  |
|               | $V_s$ - Governing shear strength of steel  | $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$  |  |
| 22.5.1.1      | $\phi V_n$ - Allowable shear strength  | $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((119.14 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.52 \text{ kip}$  |  |
|               | <b>Considering x-direction:</b><br>$V_{max} = 7.1938 \text{ kip}$ - Maximum shear force in the x-direction,<br>$Ratio$ - Capacity  | $Ratio = \frac{V_{max}}{\phi V_n}$  |  |

|           |   |  |
|-----------|---|--|
|           | $Ratio = \frac{(7.1938 \text{ kip})}{(110.52 \text{ kip})}$ $Ratio = 0.065088$ <p>Considering z-direction:</p> <p><math>V_{max} = 0.13394 \text{ kip}</math> - Maximum shear force in the z-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.13394 \text{ kip})}{(110.52 \text{ kip})}$ $Ratio = 0.0012118$ <p>Status: <b>PASS</b><br/>Ratio: <b>0.070</b></p>  |  |
| 14.5.2.1b | <p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),<br/> Allowable flexural strength:<br/> <math>M_n</math> shall be the lesser of:</p> <p><math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore,<br/> <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction:</p> <p><math>M_{max} = 18.861 \text{ kipft}</math> - Maximum moment in the x-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(18.861 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.075565$ <p>Status: <b>PASS</b><br/>Ratio: <b>0.080</b></p> |  |
|           | <p>Considering z-direction:</p> <p><math>M_{max} = 0.31338 \text{ kipft}</math> - Maximum moment in the z-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$  |  |

$$Ratio = \frac{(0.31338 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0012555$$

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

| REFERENCES     | CALCULATIONS  | RESULTS                                  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
|----------------|---|--|--|--|--|---|---|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|--------|--------|------------|--------|--------|------------|--------|--------|--|--|
|                | <div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>  |  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
|                | <div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 5.5 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa)<br/>(psf)</th><th>Allowable Lateral Pressure (R)<br/>(psf/ft)</th></tr><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></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>3.549</td><td>4.939</td></tr><tr><td>Vx (kip)</td><td>-1.737</td><td>-2.896</td></tr><tr><td>Vz (kip)</td><td>-0.117</td><td>-0.177</td></tr><tr><td>Mx (kipft)</td><td>-0.199</td><td>-0.284</td></tr><tr><td>Mz (kipft)</td><td>17.438</td><td>29.166</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div> | Layer                                    | Label                                      | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 3.549 | 4.939 | Vx (kip) | -1.737 | -2.896 | Vz (kip) | -0.117 | -0.177 | Mx (kipft) | -0.199 | -0.284 | Mz (kipft) | 17.438 | 29.166 | <div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div><math display="block">H = h_1 + h_2 + h_e</math></div> <div><math display="block">H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})</math></div> <div><math display="block">H = 0 \text{ ft}</math></div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div><math display="block">H_o = \frac{V_x}{1.57 \text{ } D}</math></div> <div><math display="block">H_o = \frac{(-1.737 \text{ kip})}{1.57 \times (48 \text{ in})}</math></div> <div><math display="block">H_o = -0.27659 \text{ kip/ft}</math></div> |  |
| Layer          | Label   | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| 1              | Sand, silty sand, clayey sand, silty gravel & clayey gravel   | 2000.000                                 | 150.000                                    |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| Load Component | ASD   | LRFD                                     |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| P (kip)        | 3.549   | 4.939                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| Vx (kip)       | -1.737  | -2.896                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| Vz (kip)       | -0.117  | -0.177                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| Mx (kipft)     | -0.199  | -0.284                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |
| Mz (kipft)     | 17.438  | 29.166                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |        |        |            |        |        |            |        |        |  |  |

|  |  |   |
|--|--|---|
|  | <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(17.438 \text{ kipft}) + ((-1.737 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 2.7768 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left( 14.14 \times \frac{H_o \times L_x}{R} \right) - \left( 18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation:<br/> <math>L_{e,x} = 5.1509 \text{ ft}</math> - Required depth in x-direction,</p> <p><b>Considering z-direction:</b></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(-0.117 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.018631 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.199 \text{ kipft}) + ((-0.117 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.031688 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_z^3 - \left( 14.14 \times \frac{H_o \times L_z}{R} \right) - \left( 18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation:<br/> <math>L_{e,z} = 1.0946 \text{ ft}</math> - Required depth in z-direction,</p> <p><b>Minimum embedded depth required:</b></p> <p><math>L_{e,req}</math> - Depth of pile required,</p> $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.1509 \text{ ft}), (1.0946 \text{ ft})]$ $L_{e,req} = 5.151 \text{ ft}$ <p><math>L_e</math> - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 5.5 \text{ ft}$ <p><b>Ratio</b> - Embedded depth</p> $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.151 \text{ ft})}{(5.5 \text{ ft})}$ $\text{Ratio} = 0.93655$ | <p>Status: <b>PASS</b><br/> Ratio: <b>0.940</b></p> |
|  | <p><b>End-bearing Capacity (ASD)</b></p> <p><math>A</math> - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p><math>q</math> - End-bearing pressure</p>   |   |

|          |  |  |
|----------|--|--|
|          | $q = \frac{P_v}{A}$ $q = \frac{(3.549 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.22181 \text{ kip/ft}^2$ <p><b>Check bearing capacity ratio:</b></p> <p>Ratio - Capacity</p> $\text{Ratio} = \frac{q}{q_a}$ $\text{Ratio} = \frac{(0.22181 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.11091$  | <p>Status: <b>PASS</b><br/>Ratio: <b>0.110</b></p> |
| Czerniak | <p><b>Lateral Soil Pressure (ASD):</b></p> <p><math>L/D</math> - Length to least lateral dimension ratio,</p> $L/D = \frac{L}{D}$ $L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$ $L/D = 1.375$ <p>Since <math>L/D \leq 10</math>,</p> <p>Pile is short.</p> <p><b>Considering x-direction:</b></p> <p><math>H_o = -0.27659 \text{ kip/ft}</math> - Lateral force per length of pile,<br/> <math>M_o = 2.7768 \text{ kipft/ft}</math> - Overturning moment per length of pile,<br/> <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (2.7768 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7768 \text{ kipft/ft})) + (4 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.7893 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (2.7768 \text{ kipft/ft})) + (3 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7768 \text{ kipft/ft})) + (2 \times (-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.20075 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (2.7768 \text{ kipft/ft})) + ((-0.27659 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.79978 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.7893 \text{ ft})}{2}$ $p_a = 0.2842 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> |  |



|  |  |   |
|--|--|---|
|  | $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.20075 \text{ kip/ft}^2)}{(0.2842 \text{ kip/ft}^2)}$ $Ratio = 0.70637$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(0.79978 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $Ratio = 0.96944$   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.710</b></p> <p>Status: <b>PASS</b><br/>Ratio: <b>0.970</b></p> |
|  | <p><b>Considering z-direction:</b></p> <p><math>H_o = -0.018631 \text{ kip/ft}</math> - Lateral force per length of pile,<br/> <math>M_o = 0.031688 \text{ kipft/ft}</math> - Overturning moment per length of pile,<br/> <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.031688 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.018631 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.031688 \text{ kipft/ft})) + (4 \times (-0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9798 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.031688 \text{ kipft/ft})) + (3 \times (-0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.031688 \text{ kipft/ft})) + (2 \times (-0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = -0.0073644 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.031688 \text{ kipft/ft})) + ((-0.018631 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = -0.0077539 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9798 \text{ ft})}{2}$ $p_a = 0.29848 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(-0.0073644 \text{ kip/ft}^2)}{(0.29848 \text{ kip/ft}^2)}$ |   |

$$Ratio = -0.024673$$

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

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

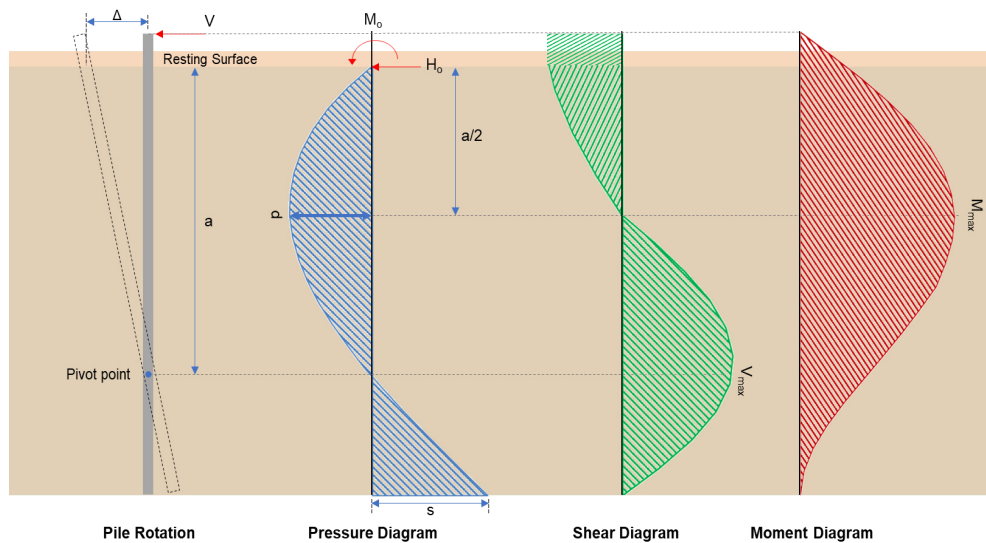
Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.0077539 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = -0.0093986$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-2.896 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.46115 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(29.166 \text{ kipft}) + ((-2.896 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6443 \text{ kipft/ft}$$

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

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

$$E = \frac{(4.6443 \text{ kipft/ft})}{(-0.46115 \text{ kip/ft})}$$

$$E = 10.071 \text{ ft}$$

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

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

$$a = \frac{(4 \times (4.6443 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.6443 \text{ kipft/ft})) + (4 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.6443 \text{ kipft/ft})) + (4 \times (-0.46115 \text{ kip/ft}) \times (5.5 \text{ ft}))}{}$$

$$a = 3.789 \text{ ft}$$

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

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

$$V_{max} = ((-0.46115 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.789 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.789 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1938 \text{ kip}$$

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

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

$$M_{max} = ((-0.46115 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(10.071 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.789 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.789 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^3 \right] + \left[ \left( \frac{3 \times (10.071 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.789 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 18.861 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.177 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.028185 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.284 \text{ kipft}) + ((-0.177 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.045223 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.045223 \text{ kipft/ft})}{(-0.028185 \text{ kip/ft})}$$

$$E = 1.6045 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.045223 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.028185 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.045223 \text{ kipft/ft})) + (4 \times (-0.028185 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9855 \text{ ft}$$

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

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

$$V_{max} = ((-0.028185 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9855 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9855 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.13394 \text{ kip}$$

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

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

$$M_{max} = ((-0.028185 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(1.6045 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (1.6045 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9855 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.31338 \text{ kipft}$$

#### 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,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

##### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = Min \left[ \frac{\frac{(4.939 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.432 \text{ in}^2$$

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

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

$$A_{min} = Max [(-84.432 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|   |   |  |
|---|---|--|
| <p>25.2.3</p>                                   | <div style="text-align: right;"><math>Ratio = 0.96556</math></div> <p><math>s_{rebar}</math> - Minimum spacing of reinforcement,</p> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> <p>25.7.2.2 Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 <math>s_{ties}</math> - Maximum spacing of ties,</p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>14 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></p>  | <p>Status: <b>PASS</b><br/>Ratio: <b>0.970</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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><math>Ratio</math> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(4.939 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0018462$   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.1.3</p> <p>22.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p><math>\lambda_s</math> - size effect modification factor</p> $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <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> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ |  |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 4.939 \text{ kip} \rightarrow 4939 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(4939 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.14 \text{ kip}$$

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)

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.14 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.14 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.14 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.52 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 7.1938 \text{ kip}$  - Maximum shear force in the x-direction,  
 $Ratio$  - Capacity

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

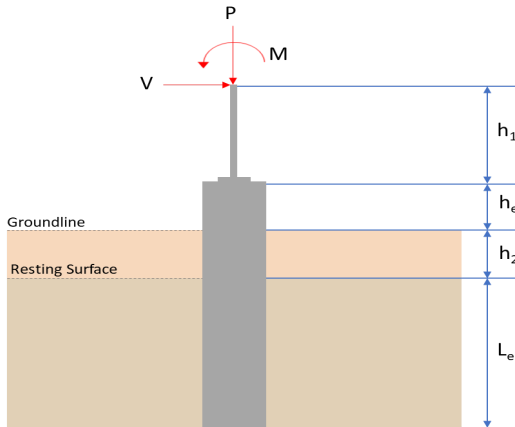
|           |  |  |
|-----------|--|--|
|           | $Ratio = \frac{(7.1938 \text{ kip})}{(110.52 \text{ kip})}$ $Ratio = 0.065088$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.13394 \text{ kip}</math> - Maximum shear force in the z-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.13394 \text{ kip})}{(110.52 \text{ kip})}$ $Ratio = 0.0012118$ <p>Status: <b>PASS</b><br/>Ratio: <b>0.070</b></p>  |  |
| 14.5.2.1b | <p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),<br/> Allowable flexural strength:<br/> <math>M_n</math> shall be the lesser of:</p> <p><math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore,<br/> <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p><b>Considering x-direction:</b></p> <p><math>M_{max} = 18.861 \text{ kipft}</math> - Maximum moment in the x-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(18.861 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.075565$ <p>Status: <b>PASS</b><br/>Ratio: <b>0.080</b></p> |  |
|           | <p><b>Considering z-direction:</b></p> <p><math>M_{max} = 0.31338 \text{ kipft}</math> - Maximum moment in the z-direction,<br/> <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$  |  |

$$Ratio = \frac{(0.31338 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0012555$$

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



| REFERENCES     | CALCULATIONS  | RESULTS                                  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
|----------------|---|--|--|--|--|---|---|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|-------|-------|------------|-------|-------|------------|--------|--------|--|--|
|                | <div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>  |  |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
|                | <div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 6 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa)<br/>(psf)</th><th>Allowable Lateral Pressure (R)<br/>(psf/ft)</th></tr><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></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>4.269</td><td>6.001</td></tr><tr><td>Vx (kip)</td><td>-2.161</td><td>-3.602</td></tr><tr><td>Vz (kip)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mx (kipft)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mz (kipft)</td><td>21.670</td><td>36.253</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div> | Layer                                    | Label                                      | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 4.269 | 6.001 | Vx (kip) | -2.161 | -3.602 | Vz (kip) | 0.000 | 0.000 | Mx (kipft) | 0.000 | 0.000 | Mz (kipft) | 21.670 | 36.253 | <div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div><math display="block">H = h_1 + h_2 + h_e</math></div> <div><math display="block">H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})</math></div> <div><math display="block">H = 0 \text{ ft}</math></div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div><math display="block">H_o = \frac{V_x}{1.57 \, D}</math></div> <div><math display="block">H_o = \frac{(-2.161 \text{ kip})}{1.57 \times (48 \text{ in})}</math></div> <div><math display="block">H_o = -0.34411 \text{ kip/ft}</math></div> |  |
| Layer          | Label   | Allowable Bearing Pressure (qa)<br>(psf) | Allowable Lateral Pressure (R)<br>(psf/ft) |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| 1              | Sand, silty sand, clayey sand, silty gravel & clayey gravel   | 2000.000                                 | 150.000                                    |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Load Component | ASD   | LRFD                                     |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| P (kip)        | 4.269   | 6.001                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Vx (kip)       | -2.161  | -3.602                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Vz (kip)       | 0.000   | 0.000                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Mx (kipft)     | 0.000   | 0.000                                    |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |
| Mz (kipft)     | 21.670  | 36.253                                   |  |  |  |   |   |          |         |                |     |      |         |       |       |          |        |        |          |       |       |            |       |       |            |        |        |  |  |

|          |   |  |
|----------|---|--|
|          | <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(21.67 \text{ kipft}) + ((-2.161 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 3.4506 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left( 14.14 \times \frac{H_o \times L_x}{R} \right) - \left( 18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation:<br/> <math>L_{e,x} = 5.465 \text{ ft}</math> - Required depth in x-direction,</p> <p><b>Considering z-direction:</b><br/> <math>L_{e,z} = 0 \text{ ft}</math> - Required depth in z-direction,</p> <p><b>Minimum embedded depth required:</b><br/> <math>L_{e,req}</math> - Depth of pile required,</p> $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.465 \text{ ft}), (0 \text{ ft})]$ $L_{e,req} = 5.465 \text{ ft}$ <p><math>L_e</math> - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 6 \text{ ft}$ <p>Ratio - Embedded depth</p> $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.465 \text{ ft})}{(6 \text{ ft})}$ $\text{Ratio} = 0.91083$ | <p>Status: <b>PASS</b><br/>Ratio: <b>0.910</b></p> |
|          | <p><b>End-bearing Capacity (ASD)</b></p> <p><math>A</math> - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p><math>q</math> - End-bearing pressure</p> $q = \frac{P_v}{A}$ $q = \frac{(4.269 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.26681 \text{ kip/ft}^2$ <p><b>Check bearing capacity ratio:</b><br/> Ratio - Capacity</p> $\text{Ratio} = \frac{q}{q_a}$ $\text{Ratio} = \frac{(0.26681 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.13341$  | <p>Status: <b>PASS</b><br/>Ratio: <b>0.130</b></p> |
| Czerniak | <p><b>Lateral Soil Pressure (ASD):</b></p> <p><math>L/D</math> - Length to least lateral dimension ratio,</p>   |  |

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

$$L/D = \frac{(6 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5$$

Since  $L/D \leq 10$ ,

Pile is short.

#### Considering x-direction:

$H_o = -0.34411 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 3.4506 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (3.4506 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.34411 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (3.4506 \text{ kipft/ft})) + (4 \times (-0.34411 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1426 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.4506 \text{ kipft/ft})) + (3 \times (-0.34411 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (3.4506 \text{ kipft/ft})) + (2 \times (-0.34411 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.19382 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (3.4506 \text{ kipft/ft})) + ((-0.34411 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.8061 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1426 \text{ ft})}{2}$$

$$p_a = 0.31069 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.19382 \text{ kip/ft}^2)}{(0.31069 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.62383$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6 \text{ ft})$$

$$p_s = 0.9 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

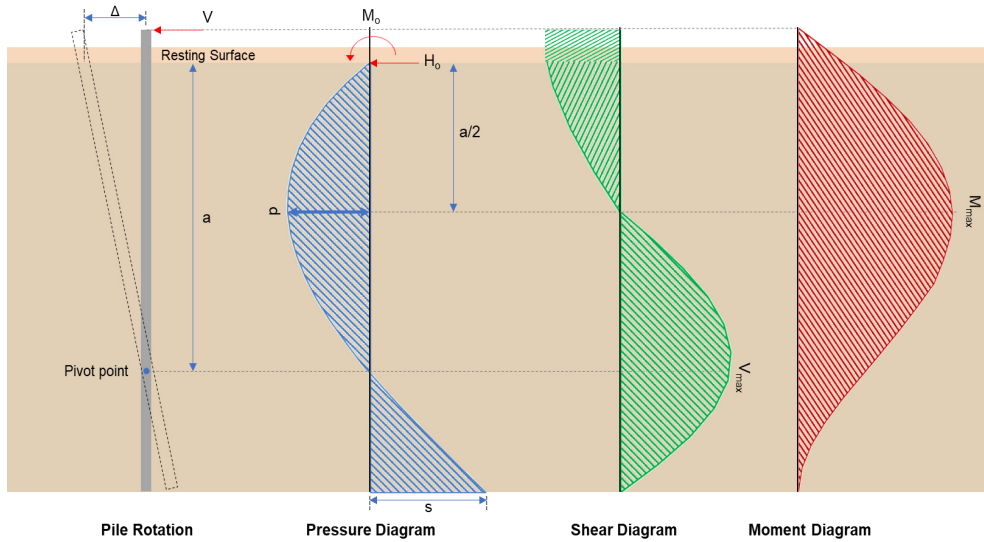
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(0.8061 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

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

$$Ratio = 0.89567$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.602 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.57357 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(36.253 \text{ kipft}) + ((-3.602 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.7728 \text{ kipft/ft}$$

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

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

$$E = \frac{(5.7728 \text{ kipft/ft})}{(-0.57357 \text{ kip/ft})}$$

$$E = 10.065 \text{ ft}$$

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

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

$$a = \frac{(4 \times (5.7728 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.57357 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (5.7728 \text{ kipft/ft})) + (4 \times (-0.57357 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1422 \text{ ft}$$

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

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

$$V_{max} = ((-0.57357 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.065 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1422 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.065 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1422 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

|  |  |   |  |
|--|--|---|--|
|  |  | $v_{max} = 0.323 \text{ kip}$   |  |
|  |  | <p><math>M_{max}</math> - Max bending moment located at depth <math>a/2</math>,</p> $M_{max} = (H_o D L_e) \left[ \left( \frac{E}{L_e} + \frac{a}{2 L_e} \right) - \left[ \left( \frac{4 E}{L_e} + 3 \right) \left( \frac{a}{2 L_e} \right)^3 + \left[ \left( \frac{3 E}{L_e} + 2 \right) \left( \frac{a}{2 L_e} \right)^4 \right] \right] \right]$ $M_{max} = ((-0.57357 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[ \left( \frac{(10.065 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1422 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.065 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1422 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (10.065 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1422 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right] \right]$ $M_{max} = 23.72 \text{ kipft}$  |  |
|  |  | <p><b>Minimum Reinforcement Check (LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>f'_{ck} = 2.5 \text{ ksi}</math> - Concrete strength,<br/> <math>f_{yk} = 60 \text{ ksi}</math> - Longitudinal reinforcement strength,<br/> <math>\phi = 0.65</math> - Reduction factor for axial strength,<br/> <math>\alpha = 0.8</math> - Alpha factor for axial strength,<br/> <math>A_g = 2304 \text{ in}^2</math> - Gross area of concrete,</p> <p><b>Longitudinal reinforcement:</b></p> <p>Required reinforcement due to axial load, <math>A_{st,required}</math></p> $A_{st,required} = \text{Min} \left[ \frac{\frac{P}{\phi \alpha} - (0.85 f'_{ck} A_g)}{f_{yk} - (0.85 f'_{ck})}, (0.08 A_g) \right]$ $A_{st,required} = \text{Min} \left[ \frac{\frac{(6.001 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$ $A_{st,required} = -84.397 \text{ in}^2$ <p><math>A_{min}</math> - Governing minimum reinforcement area,</p> $A_{min} = \text{Max} [A_{st,required}, (0.0018 A_g)]$ $A_{min} = \text{Max} [(-84.397 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$ $A_{min} = 4.1472 \text{ in}^2$ <p><math>n_{rebar}</math> - Required number of reinforcement,</p> $n_{rebar} = \frac{A_{min}}{A_{rebar}}$ $n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$ $n_{rebar} = 14$ <p><math>A_{st}</math> - Actual total reinforcement area,</p> $A_{st} = n_{rebar} \frac{\pi d_{bar}^2}{4}$ $A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$ $A_{st} = 4.2951 \text{ in}^2$ <p><b>Ratio - Capacity</b></p> $\text{Ratio} = \frac{A_{min}}{A_{st}}$ $\text{Ratio} = \frac{(4.1472 \text{ in}^2)}{(4.2951 \text{ in}^2)}$ $\text{Ratio} = 0.96556$ |  |
|  |  | <p><math>s_{rebar}</math> - Minimum spacing of reinforcement,</p> $s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$   |  |
|  |  |   | <p>Status: <b>PASS</b><br/>Ratio: <b>0.970</b></p> |

|               |  |  |
|---------------|--|--|
|               | <div><math display="block">s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]</math><math display="block">s_{rebar} = 1.5 \text{ in}</math></div> <div><b>Ties:</b><br/>Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)<br/><math>s_{ties}</math> - Maximum spacing of ties,<br/><math display="block">s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math><math display="block">s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math><math display="block">s_{ties} = 10 \text{ in}</math></div> <div><b>Summary:</b><br/><br/>Main reinforcement: <b>14 - #5 (0.625 in)</b><br/>Ties: <b>#3(0.375 in) - 10 in</b></div> |  |
| 22.4.2.2      | <div><b>Axial Compression Strength (ACI 318-19, LRFD)</b><br/><math>\phi P_N</math> - Allowable axial compressive strength<br/><math display="block">\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math><math display="block">\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]</math><math display="block">\phi P_N = 2675.2 \text{ kip}</math><br/><i>Ratio</i> - Capacity<br/><math display="block">Ratio = \frac{P}{\phi P_N}</math><math display="block">Ratio = \frac{(6.001 \text{ kip})}{(2675.2 \text{ kip})}</math><math display="block">Ratio = 0.0022432</math></div>      | Status: <b>PASS</b><br>Ratio: <b>0.000</b> |
| 22.5.2.2      | <div><b>Shear Strength (ACI 318-19, LRFD)</b><br/><b>Parameters:</b><br/><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth<br/><math display="block">d = 0.80 D</math><math display="block">d = 0.80 \times (48 \text{ in})</math><math display="block">d = 38.4 \text{ in}</math></div>  |  |
| 22.5.5.1.3    | <div><math>\lambda_s</math> - size effect modification factor<br/><math display="block">\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math><math display="block">\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]</math><math display="block">\lambda_s = 0.64282</math></div>   |  |
| 22.5.5.1.1    | <div>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>,<br/><math>V_{c,max}</math> - Max shear strength of concrete<br/><math display="block">V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math><math display="block">V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math><math display="block">V_{c,max} = 296.21 \text{ kip}</math></div>  |  |
| 22.5.5.1.1(a) | <div>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>, <math>P = 6.001 \text{ kip} \rightarrow 6001 \text{ lbf}</math>,<br/><math>V_{c,a}</math> - Shear strength of concrete (a)<br/><math display="block">V_{c,a} = \left[ 2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d</math></div>   |  |

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(6001 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.29 \text{ kip}$$

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)

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.29 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.29 \text{ kip}$$

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)

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.29 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.62 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 8.323 \text{ kip}$  - Maximum shear force in the x-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(8.323 \text{ kip})}{(110.62 \text{ kip})}$$

$$\text{Ratio} = 0.075242$$

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

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

$S_m$  - Section modulus

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

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

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

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 23.72 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(23.72 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.095031$$

Status: **PASS**  
Ratio: **0.100**