

# Project Details



**Project Name:** Carnegie Building - V1Jb

**Date:** Fri Dec 20 2024

**Location:** Yreka, CA 96097, USA

**Number of Modules:** 55

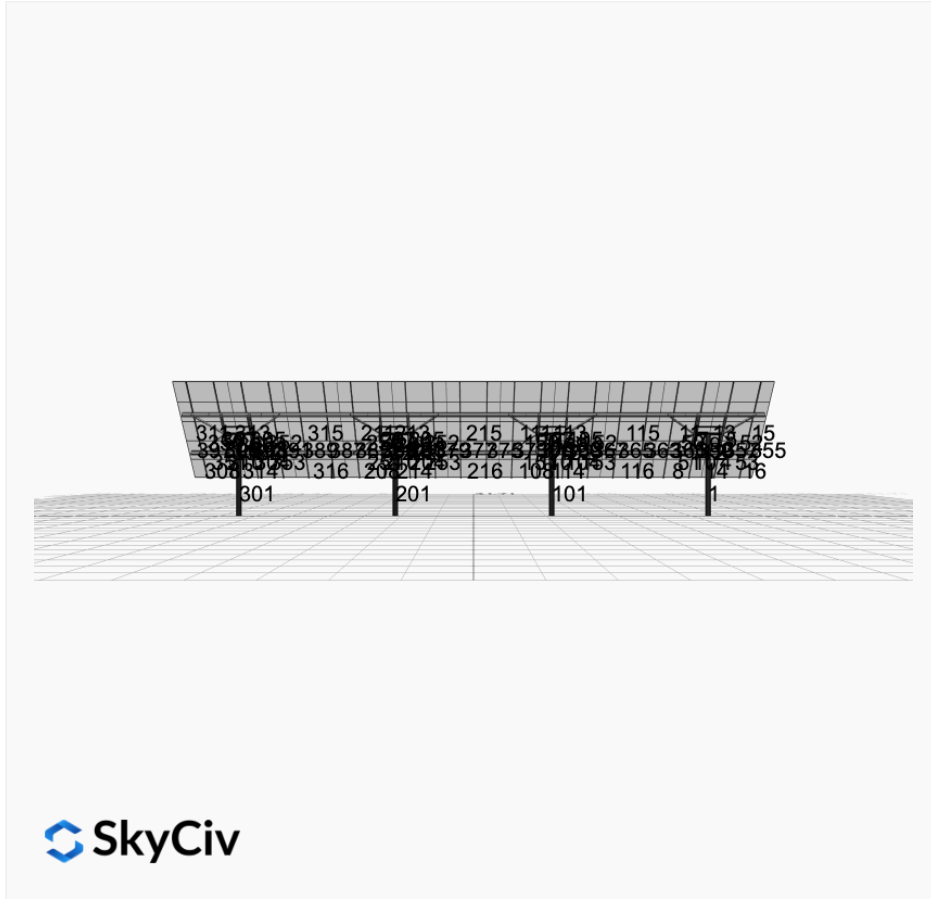
**Unique ID:** 4P-22.5-8TOP-HD-45-L-5Hx11W-STRUTS-47GH

**Number of Poles:** 4

**Date Sold:**

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

\_\_\_\_\_



|                             |          |
|-----------------------------|----------|
| <b>Array Dimensions N/S</b> | 18.79 ft |
| <b>Array Dimensions E/W</b> | 83.42 ft |
| <b>Winter Tilt Angle</b>    | 46       |
| <b>Front Edge Clearance</b> | 5 ft     |

## MT Solar Bill of Materials (4P-22.5-8TOP-HD-45-L-5Hx11W-STRUTS-47GH)

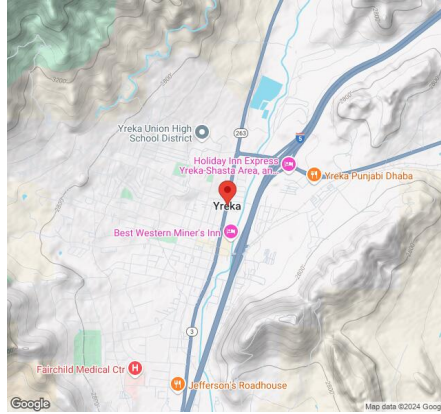
| Part                | Short Description     | BOM Qty |
|---------------------|-----------------------|---------|
| MTS-PC-8            | 8IN Pole Cap Assembly | 4       |
| MTS-HF-HD           | H-Frame Assembly-HD   | 4       |
| MTS-HD-Wing-45      | 45IN HD Wing          | 4       |
| MTS-HD-Splice-90    | 90IN HD Splice        | 12      |
| MTS-CLAMP-ANGLE-4PK | Angle Clamp           | 11      |

## Rail Bill of Materials

| Part             | Qty |
|------------------|-----|
| Rails (223in)    | 22  |
| Rail Attachment  | 88  |
| Module Mid Clamp | 88  |

| <b>Part</b>      | <b>Qty</b> |
|------------------|------------|
| Module End Clamp | 44         |
| Ground Lug       | 11         |

## Site Details:



**Site Address:** Yreka, CA 96097, USA

### Array Specification

|                                    |           |
|------------------------------------|-----------|
| <b>Duty Classification:</b>        | HD        |
| <b>Module Width:</b>               | 44.60 in  |
| <b>Module Length:</b>              | 90.00in   |
| <b>Number of Rows:</b>             | 5         |
| <b>Number of Columns:</b>          | 11        |
| <b>Total Number of Modules:</b>    | 55        |
| <b>Winter Tilt Angle:</b>          | 46        |
| <b>Front Edge Clearance:</b>       | 5         |
| <b>Total Array Height at Tilt:</b> | 18.52 ft  |
| <b>Total Frame Length:</b>         | 82.50 ft  |
| <b>Frame Weight:</b>               | 5301 lbs  |
| <b>Array Dimensions N/S:</b>       | 18.79 ft  |
| <b>Array Dimensions E/W:</b>       | 83.42 ft  |
| <b>Rail Length:</b>                | 225.50 in |
| <b>Rail Spacing:</b>               | 3.79 ft   |

### Support Specifications

|                                 |                 |
|---------------------------------|-----------------|
| <b>Pole Size:</b>               | 8in Pipe Sch 40 |
| <b>Pole Length above Grade:</b> | 11.76 ft        |
| <b>Number of Poles:</b>         | 4               |
| <b>Pole Spacing:</b>            | 22.5 ft         |

### Foundation Specifications

|                                        |                                                                          |
|----------------------------------------|--------------------------------------------------------------------------|
| <b>Foundation Type:</b>                | Square                                                                   |
| <b>Foundation Dimensions:</b>          | 48 x 48 in                                                               |
| <b>Foundation Depth (below grade):</b> | Pile 1: 5.75 ft<br>Pile 2: 6.00 ft<br>Pile 3: 6.00 ft<br>Pile 4: 5.75 ft |
| <b>Foundation Volume:</b>              | 13.926 y <sup>3</sup>                                                    |

### Site Info

|                             |                      |
|-----------------------------|----------------------|
| <b>Risk Category:</b>       | I                    |
| <b>Exposure:</b>            | B                    |
| <b>Soil Classification:</b> | sand                 |
| <b>Site Location:</b>       | Yreka, CA 96097, USA |
| <b>Wind Speed:</b>          | 90 mph               |

**Snow Load:**

54 psf

### **Design Disclaimer**

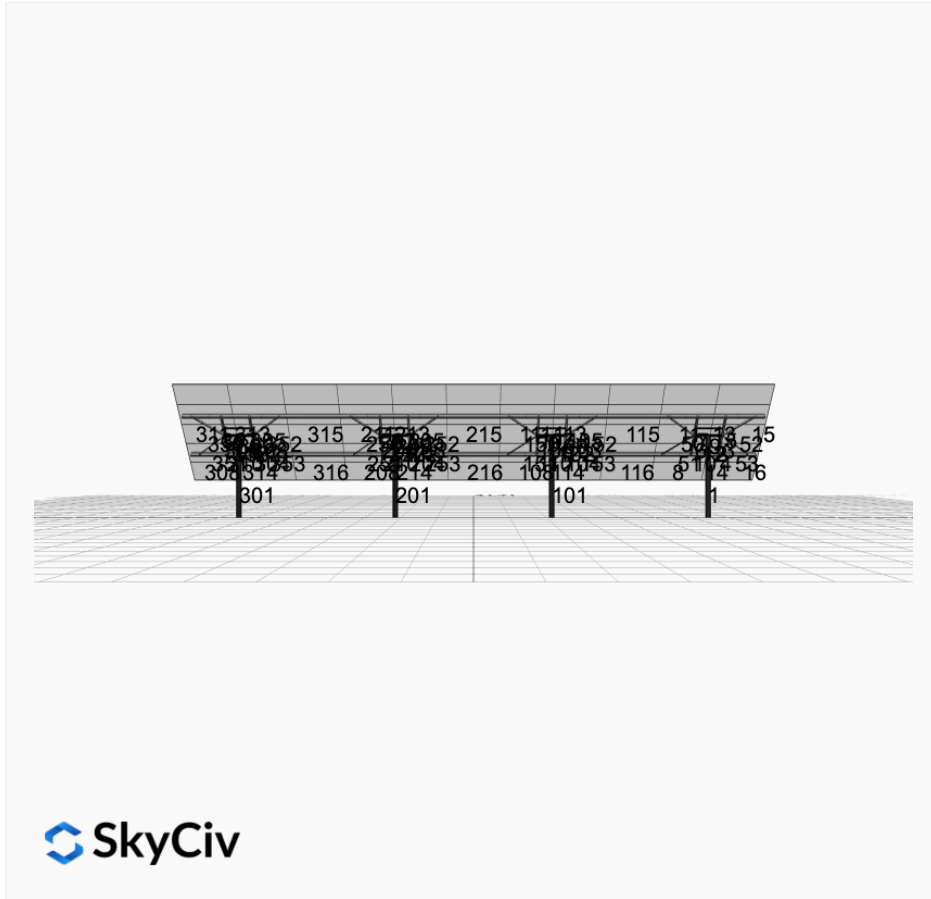
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

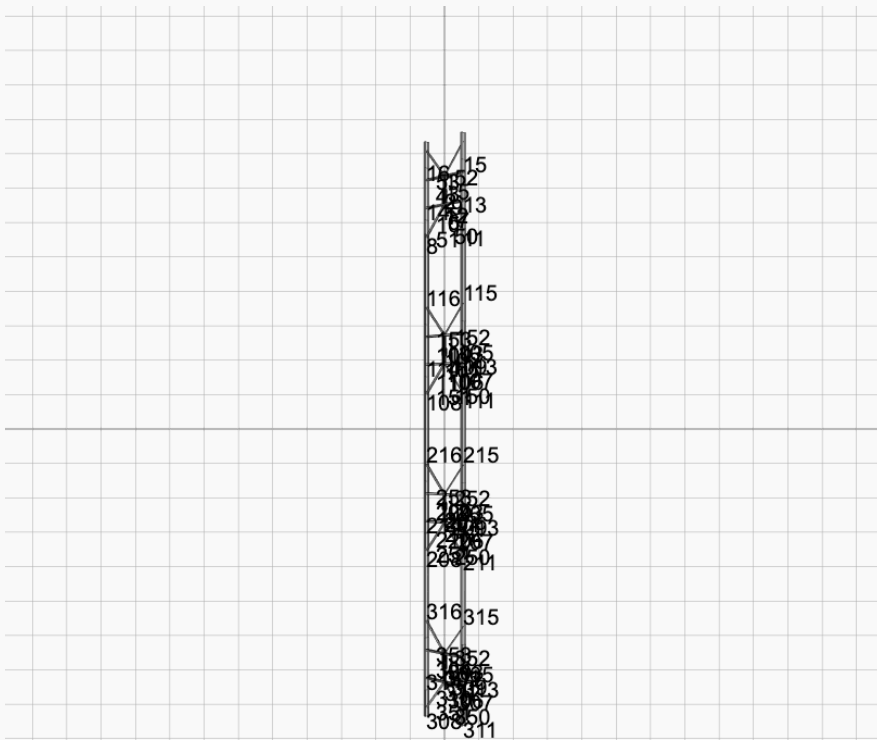
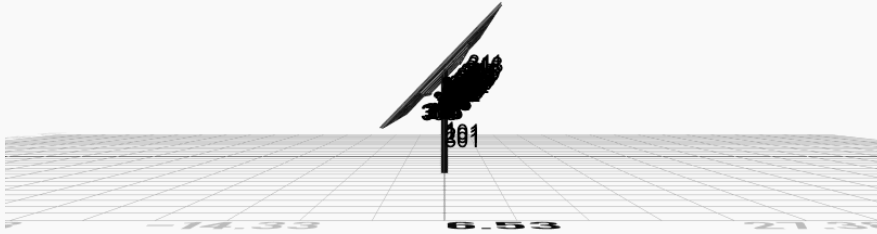
## AutoDesigner Input

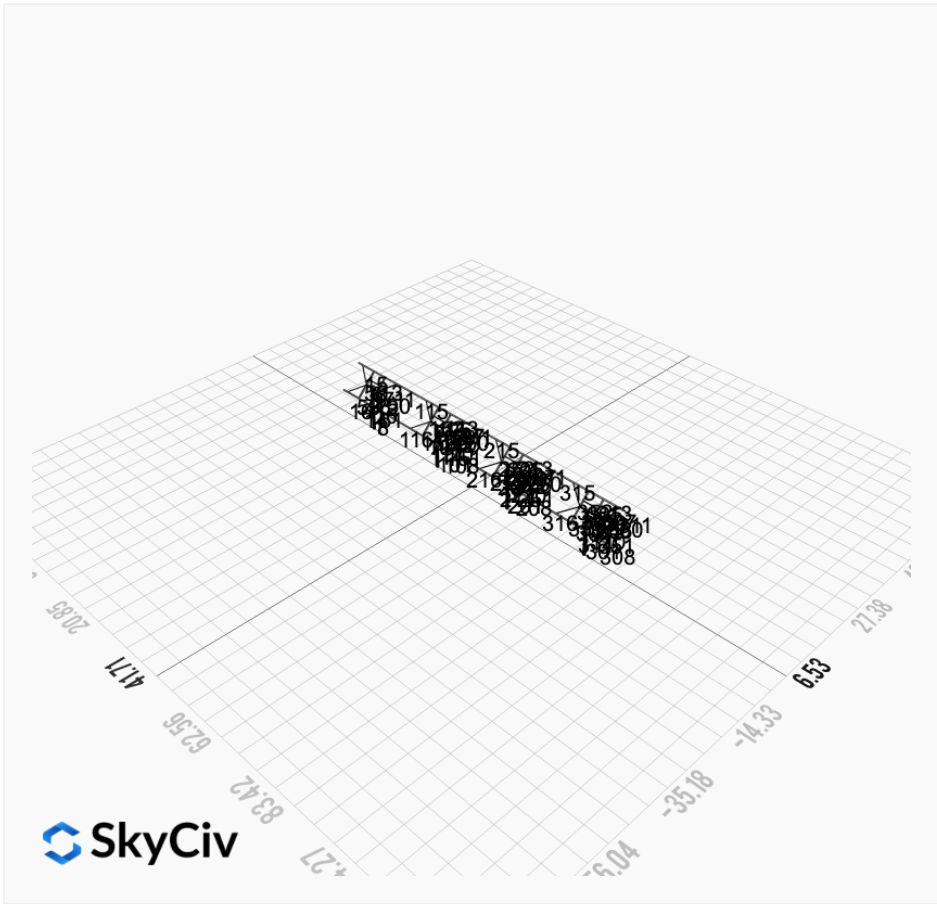
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```

### 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)

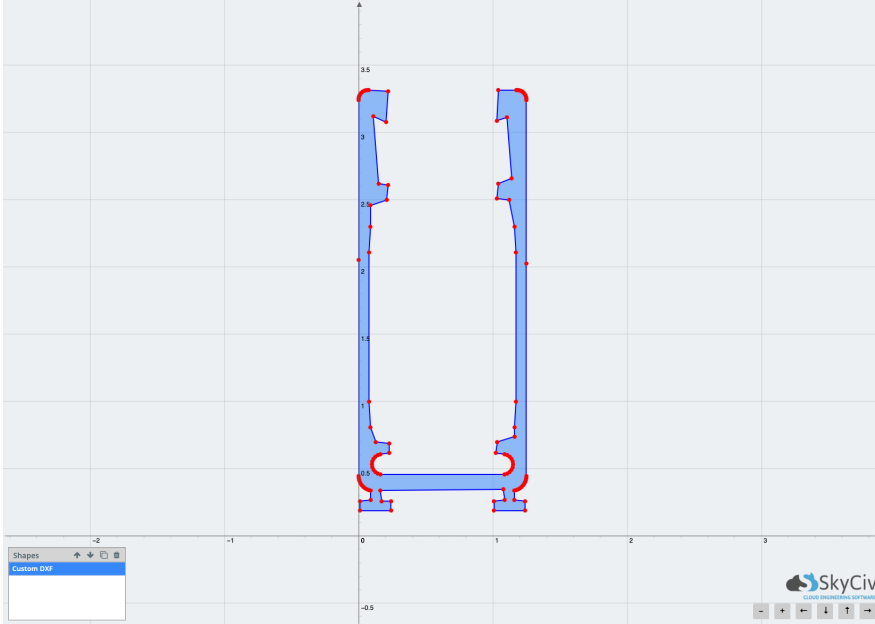






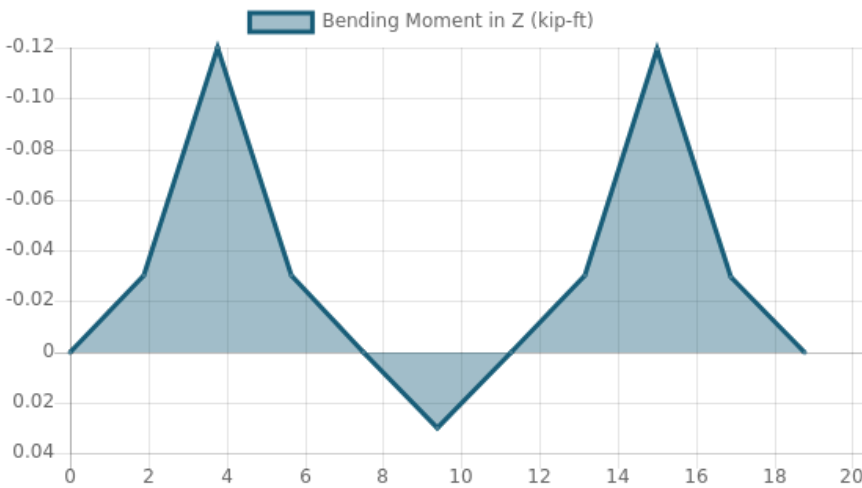
## Rail Design Check

**Rail Length:** 18.79166666666668 ft  
**Additional Restraints Required:** 4ft Spread Clamps  
**Tributary Width:** 3.79166666666665 ft  
**Material:** Aluminium  
**Density:** 169 lb/ft<sup>3</sup>  
**Elasticity Modulus:** 10000 ksi  
**Fy:** 34.5 ksi  
**Fu:** 37 ksi  
**Snow (X):** 0.0375 kip/ft  
**Snow (Y):** -0.0389 kip/ft  
**Wind uplift Case A:** 0.0382 kip/ft  
**Wind downforce Case A:** 0.0382 kip/ft  
**Dead (Panel load) (X):** 0.0116 kip/ft  
**Dead (Panel load) (Y):** -0.0121 kip/ft

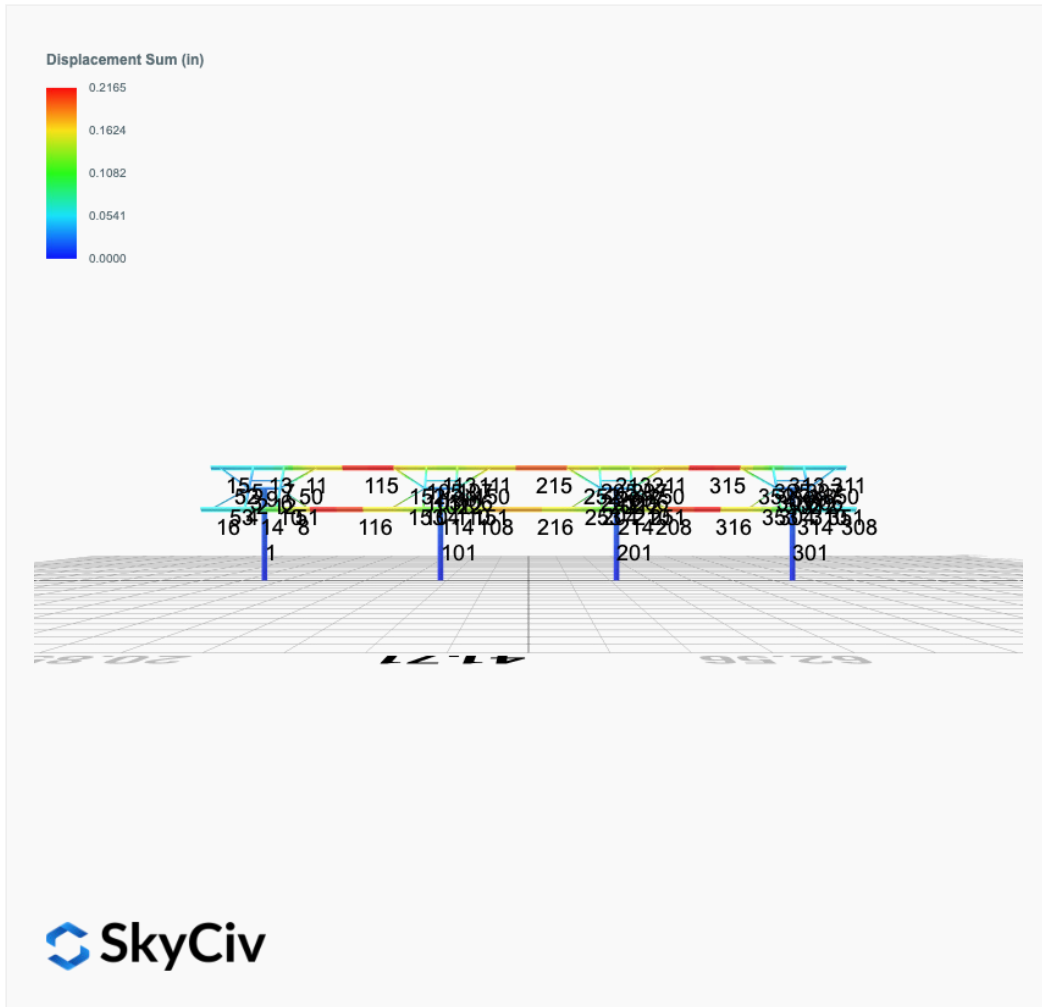


| Result Check        | Max Limit | Max Value   | Utility | Status |
|---------------------|-----------|-------------|---------|--------|
| Custom Stress Limit | 34.5      | 14.85134976 | 0.430   | PASS   |
| Material Yield      | 34.5      | 14.85134976 | 0.430   | PASS   |
| Material Strength   | 37        | 14.85134976 | 0.401   | PASS   |

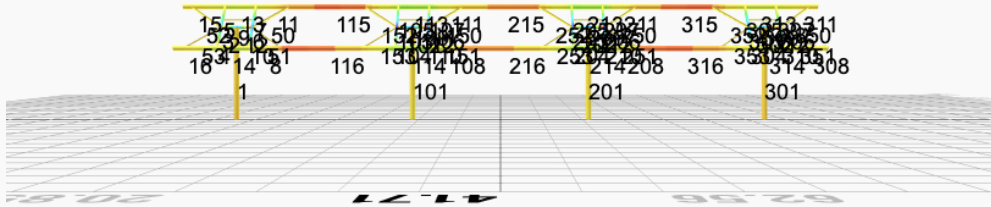
Member 1, ULS: 1. 1.4D



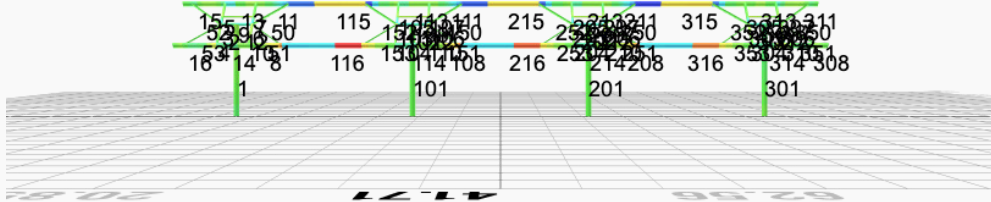
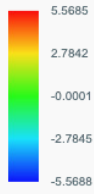
# FEM Results (Envelope Worst Case for each member)



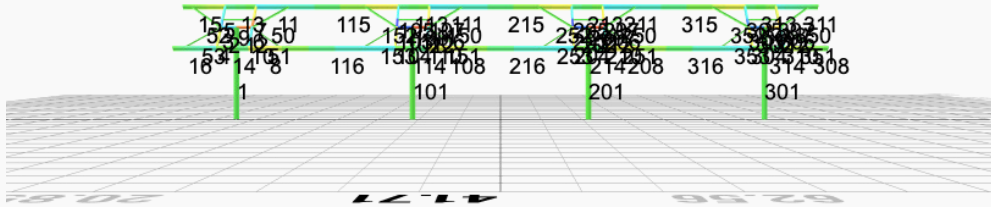
Top Bending Stress Z (ksi)



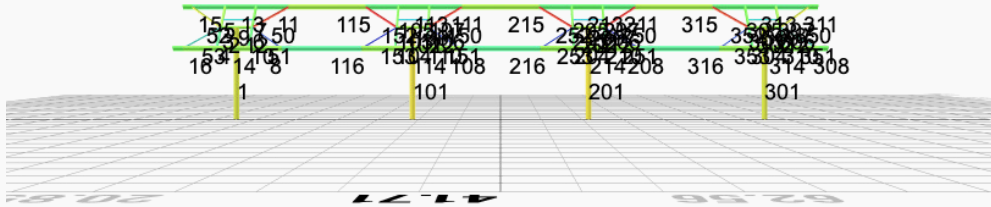
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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

### ASD Load Combination Results

| Name                                                                            | Fx      | Fy     | Fz      | Mx      | My      | Mz       |
|---------------------------------------------------------------------------------|---------|--------|---------|---------|---------|----------|
| ULS: 1. D                                                                       | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 2. D + L                                                                   | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 3. D + (S or Lr or R)                                                      | 0.0587  | 5.9794 | 0.1727  | 0.5991  | -0.3561 | -0.6197  |
| ULS: 3. D + (S or Lr or R)                                                      | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)                                          | 0.0492  | 5.1203 | 0.1448  | 0.5025  | -0.2984 | -0.5175  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)                                          | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 5b. D + 0.7E                                                               | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S                                         | 0.0492  | 5.1203 | 0.1448  | 0.5025  | -0.2984 | -0.5175  |
| ULS: 8. 0.6D + 0.7E                                                             | 0.0125  | 1.5258 | 0.0368  | 0.1275  | -0.0752 | -0.1265  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -1.5300 | 3.9829 | 0.1582  | 0.5408  | -0.5545 | 18.2438  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 1.5695  | 1.1037 | -0.0346 | -0.1120 | 0.2993  | -18.3596 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.1139 | 6.2002 | 0.2175  | 0.7486  | -0.6204 | 13.3235  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0492  | 5.1203 | 0.1448  | 0.5025  | -0.2984 | -0.5175  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.2107  | 4.0408 | 0.0729  | 0.2590  | 0.0200  | -14.1291 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0492  | 5.1203 | 0.1448  | 0.5025  | -0.2984 | -0.5175  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.1423 | 3.6229 | 0.1340  | 0.4587  | -0.4472 | 13.6302  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.1824  | 1.4635 | -0.0106 | -0.0309 | 0.1932  | -13.8224 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0208  | 2.5430 | 0.0613  | 0.2126  | -0.1253 | -0.2108  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -1.5384 | 2.9657 | 0.1337  | 0.4557  | -0.5044 | 18.3282  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | 0.0125  | 1.5258 | 0.0368  | 0.1275  | -0.0752 | -0.1265  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 1.5612  | 0.0865 | -0.0591 | -0.1971 | 0.3495  | -18.2753 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | 0.0125  | 1.5258 | 0.0368  | 0.1275  | -0.0752 | -0.1265  |

### Worst Case Reactions LRFD

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

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 9.7480              |
| Shear X          | -2.6270             |
| Shear Z          | 0.3365              |
| Moment X         | 1.1641              |
| Moment Y (Twist) | 0.9938              |
| Moment Z         | 31.2159             |

### Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 6.2002              |
| Shear X          | -1.5695             |
| Shear Z          | 0.2175              |
| Moment X         | 0.7486              |
| Moment Y (Twist) | 0.6204              |
| Moment Z         | 18.3596             |

## 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                              | -0.0208 | 2.9902 | -0.0052 | -0.0176 | 0.0213 | 0.2623 |
| ULS: 2. D + L                          | -0.0208 | 2.9902 | -0.0052 | -0.0176 | 0.0213 | 0.2623 |
| ULS: 3. D + (S or Lr or R)             | -0.0587 | 7.2277 | -0.0148 | -0.0497 | 0.0602 | 0.7250 |
| ULS: 3. D + (S or Lr or R)             | -0.0208 | 2.9902 | -0.0052 | -0.0176 | 0.0213 | 0.2623 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0492 | 6.1684 | -0.0124 | -0.0417 | 0.0504 | 0.6093 |

| Name                                                                            | Fx      | Fy      | Fz      | Mx      | My      | Mz       |
|---------------------------------------------------------------------------------|---------|---------|---------|---------|---------|----------|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)                                          | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 5b. D + 0.7E                                                               | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S                                         | -0.0492 | 6.1684  | -0.0124 | -0.0417 | 0.0504  | 0.6093   |
| ULS: 8. 0.6D + 0.7E                                                             | -0.0125 | 1.7941  | -0.0031 | -0.0106 | 0.0128  | 0.1574   |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -1.8753 | 4.8389  | -0.0009 | -0.0015 | -0.0148 | 22.2039  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 1.8358  | 1.1410  | -0.0091 | -0.0323 | 0.0547  | -21.2860 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.4401 | 7.5549  | -0.0091 | -0.0296 | 0.0233  | 17.0655  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0492 | 6.1684  | -0.0124 | -0.0417 | 0.0504  | 0.6093   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3433  | 4.7815  | -0.0153 | -0.0527 | 0.0755  | -15.5519 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0492 | 6.1684  | -0.0124 | -0.0417 | 0.0504  | 0.6093   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.4117 | 4.3767  | -0.0020 | -0.0055 | -0.0058 | 16.7185  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3717  | 1.6033  | -0.0082 | -0.0287 | 0.0464  | -15.8989 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0208 | 2.9902  | -0.0052 | -0.0176 | 0.0213  | 0.2623   |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -1.8670 | 3.6428  | 0.0012  | 0.0055  | -0.0234 | 22.0989  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -0.0125 | 1.7941  | -0.0031 | -0.0106 | 0.0128  | 0.1574   |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 1.8442  | -0.0551 | -0.0070 | -0.0253 | 0.0462  | -21.3909 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | -0.0125 | 1.7941  | -0.0031 | -0.0106 | 0.0128  | 0.1574   |

### 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            | 11.9105             |
| Shear X          | -3.1322             |
| Shear Z          | -0.0255             |
| Moment X         | -0.0871             |
| Moment Y (Twist) | 0.1187              |
| Moment Z         | 37.8536             |

### Worst Case Reactions ASD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 7.5549              |
| Shear X          | -1.8753             |
| Shear Z          | -0.0153             |
| Moment X         | -0.0527             |
| Moment Y (Twist) | 0.0755              |
| Moment Z         | 22.2039             |

### 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                                    | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 2. D + L                                | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 3. D + (S or Lr or R)                   | -0.0587 | 7.2277 | 0.0148 | 0.0497 | -0.0601 | 0.7250   |
| ULS: 3. D + (S or Lr or R)                   | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | -0.0492 | 6.1684 | 0.0124 | 0.0417 | -0.0504 | 0.6093   |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)       | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 5b. D + 0.7E                            | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S      | -0.0492 | 6.1684 | 0.0124 | 0.0417 | -0.0504 | 0.6093   |
| ULS: 8. 0.6D + 0.7E                          | -0.0125 | 1.7941 | 0.0031 | 0.0106 | -0.0128 | 0.1574   |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.8753 | 4.8389 | 0.0009 | 0.0015 | 0.0149  | 22.2039  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |
| ULS: 5a. D + 0.6W_Wind uplift Case A only    | 1.8358  | 1.1410 | 0.0091 | 0.0323 | -0.0547 | -21.2860 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only    | -0.0208 | 2.9902 | 0.0052 | 0.0176 | -0.0213 | 0.2623   |

| 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 | -1.4401 | 7.5549  | 0.0091  | 0.0296  | -0.0233 | 17.0655  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0492 | 6.1684  | 0.0124  | 0.0417  | -0.0504 | 0.6093   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3433  | 4.7815  | 0.0153  | 0.0527  | -0.0755 | -15.5519 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0492 | 6.1684  | 0.0124  | 0.0417  | -0.0504 | 0.6093   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.4117 | 4.3767  | 0.0020  | 0.0056  | 0.0058  | 16.7185  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0208 | 2.9902  | 0.0052  | 0.0176  | -0.0213 | 0.2623   |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.3717  | 1.6033  | 0.0082  | 0.0287  | -0.0464 | -15.8989 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | -0.0208 | 2.9902  | 0.0052  | 0.0176  | -0.0213 | 0.2623   |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only                                  | -1.8670 | 3.6428  | -0.0012 | -0.0055 | 0.0234  | 22.0989  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only                                  | -0.0125 | 1.7941  | 0.0031  | 0.0106  | -0.0128 | 0.1574   |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only                                     | 1.8442  | -0.0551 | 0.0070  | 0.0253  | -0.0462 | -21.3909 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only                                     | -0.0125 | 1.7941  | 0.0031  | 0.0106  | -0.0128 | 0.1574   |

### 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            | 11.9105             |
| Shear X          | -3.1322             |
| Shear Z          | 0.0254              |
| Moment X         | 0.0875              |
| Moment Y (Twist) | 0.1186              |
| Moment Z         | 37.8536             |

### Worst Case Reactions ASD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 7.5549              |
| Shear X          | -1.8753             |
| Shear Z          | 0.0153              |
| Moment X         | 0.0527              |
| Moment Y (Twist) | 0.0755              |
| Moment Z         | 22.2039             |

### Reaction Forces for Foundation 4 (Node ID#301), (kip, kip-ft)

#### ASD Load Combination Results

| Name                                                                            | Fx      | Fy     | Fz      | Mx      | My      | Mz       |
|---------------------------------------------------------------------------------|---------|--------|---------|---------|---------|----------|
| ULS: 1. D                                                                       | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 2. D + L                                                                   | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 3. D + (S or Lr or R)                                                      | 0.0587  | 5.9794 | -0.1727 | -0.5991 | 0.3561  | -0.6197  |
| ULS: 3. D + (S or Lr or R)                                                      | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)                                          | 0.0492  | 5.1203 | -0.1448 | -0.5025 | 0.2984  | -0.5175  |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R)                                          | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 5b. D + 0.7E                                                               | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S                                         | 0.0492  | 5.1203 | -0.1448 | -0.5025 | 0.2984  | -0.5175  |
| ULS: 8. 0.6D + 0.7E                                                             | 0.0125  | 1.5258 | -0.0368 | -0.1275 | 0.0752  | -0.1265  |
| ULS: 5a. D + 0.6W_Wind downforce Case A only                                    | -1.5300 | 3.9829 | -0.1582 | -0.5408 | 0.5545  | 18.2439  |
| ULS: 5a. D + 0.6W_Wind downforce Case B only                                    | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 5a. D + 0.6W_Wind uplift Case A only                                       | 1.5695  | 1.1037 | 0.0346  | 0.1120  | -0.2993 | -18.3596 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only                                       | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.1139 | 6.2002 | -0.2175 | -0.7486 | 0.6204  | 13.3235  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0492  | 5.1203 | -0.1448 | -0.5025 | 0.2984  | -0.5175  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.2107  | 4.0408 | -0.0729 | -0.2590 | -0.0200 | -14.1291 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0492  | 5.1203 | -0.1448 | -0.5025 | 0.2984  | -0.5175  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.1423 | 3.6229 | -0.1340 | -0.4587 | 0.4472  | 13.6302  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only    | 1.1824  | 1.4635 | 0.0106  | 0.0309  | -0.1932 | -13.8224 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only    | 0.0208  | 2.5430 | -0.0613 | -0.2126 | 0.1253  | -0.2108  |

| Name                                           | Fx      | Fy     | Fz      | Mx      | My      | Mz       |
|------------------------------------------------|---------|--------|---------|---------|---------|----------|
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.5384 | 2.9657 | -0.1337 | -0.4557 | 0.5044  | 18.3282  |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0125  | 1.5258 | -0.0368 | -0.1275 | 0.0752  | -0.1265  |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only    | 1.5612  | 0.0865 | 0.0591  | 0.1971  | -0.3494 | -18.2753 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only    | 0.0125  | 1.5258 | -0.0368 | -0.1275 | 0.0752  | -0.1265  |

### Worst Case Reactions LRFD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 9.7481              |
| Shear X          | -2.6270             |
| Shear Z          | -0.3365             |
| Moment X         | -1.1640             |
| Moment Y (Twist) | 0.9940              |
| Moment Z         | 31.2159             |

### Worst Case Reactions ASD

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

| Result           | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial            | 6.2002              |
| Shear X          | -1.5695             |
| Shear Z          | -0.2175             |
| Moment X         | -0.7486             |
| Moment Y (Twist) | 0.6204              |
| Moment Z         | 18.3596             |

# Project Details

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

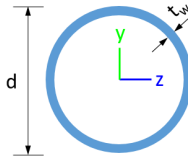


# Design Input Information

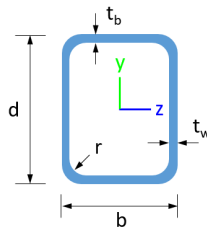
| Design Factors |          |          |          |
|----------------|----------|----------|----------|
| $\Phi_t$       | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9            | 0.9      | 0.9      | 0.9      |

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

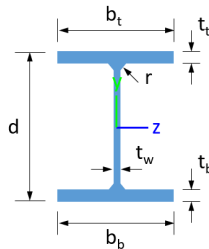
## Section Dimensions



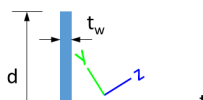
| ID | Name            | d (in) | $t_w$ (in) |  |  |  |  |
|----|-----------------|--------|------------|--|--|--|--|
| 2  | 2in Pipe Sch 80 | 2.38   | 0.22       |  |  |  |  |
| 5  | 4in Pipe Sch 80 | 4.50   | 0.34       |  |  |  |  |
| 9  | 8in Pipe Sch 40 | 8.63   | 0.32       |  |  |  |  |



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



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









|     |        |        |       |       |        |        |
|-----|--------|--------|-------|-------|--------|--------|
| 10  | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 11  | 133.20 | 123.95 | 32.87 | 6.12  | 40.24  | 43.62  |
| 12  | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 13  | 133.20 | 85.85  | 24.18 | 6.12  | 40.24  | 43.62  |
| 14  | 133.20 | 85.85  | 24.41 | 6.12  | 40.24  | 43.62  |
| 15  | 133.20 | 107.59 | 32.87 | 6.12  | 40.24  | 43.62  |
| 16  | 133.20 | 107.59 | 32.87 | 6.12  | 40.24  | 43.62  |
| 50  | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 51  | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 52  | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 53  | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 101 | 377.97 | 179.63 | 83.29 | 83.29 | 113.39 | 113.39 |
| 102 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 104 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 105 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 106 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 107 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 108 | 133.20 | 123.95 | 32.87 | 6.12  | 40.24  | 43.62  |
| 109 | 66.48  | 58.89  | 3.82  | 3.82  | 19.94  | 19.94  |
| 110 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 111 | 133.20 | 123.95 | 32.87 | 6.12  | 40.24  | 43.62  |
| 112 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 113 | 133.20 | 85.85  | 23.58 | 6.12  | 40.24  | 43.62  |
| 114 | 133.20 | 85.85  | 23.58 | 6.12  | 40.24  | 43.62  |
| 115 | 133.20 | 19.55  | 12.15 | 6.12  | 40.24  | 43.62  |
| 116 | 133.20 | 19.55  | 12.43 | 6.12  | 40.24  | 43.62  |
| 150 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 151 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 152 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 153 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 201 | 377.97 | 179.63 | 83.29 | 83.29 | 113.39 | 113.39 |
| 202 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 203 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 204 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 205 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 206 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 207 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 208 | 133.20 | 123.95 | 32.87 | 6.12  | 40.24  | 43.62  |
| 209 | 66.48  | 58.89  | 3.82  | 3.82  | 19.94  | 19.94  |
| 210 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 211 | 133.20 | 123.95 | 32.87 | 6.12  | 40.24  | 43.62  |
| 212 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 213 | 133.20 | 85.85  | 23.58 | 6.12  | 40.24  | 43.62  |
| 214 | 133.20 | 85.85  | 23.58 | 6.12  | 40.24  | 43.62  |
| 215 | 133.20 | 19.55  | 11.57 | 6.12  | 40.24  | 43.62  |
| 216 | 133.20 | 19.55  | 12.36 | 6.12  | 40.24  | 43.62  |
| 250 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 251 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 252 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 253 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 301 | 377.97 | 179.63 | 83.29 | 83.29 | 113.39 | 113.39 |

|     |        |        |       |       |        |        |
|-----|--------|--------|-------|-------|--------|--------|
| 301 | 377.97 | 179.03 | 93.29 | 93.29 | 119.99 | 119.99 |
| 302 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 303 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 304 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 305 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 306 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08  | 23.28  |
| 307 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08  | 23.28  |
| 308 | 133.20 | 107.59 | 32.87 | 6.12  | 40.24  | 43.62  |
| 309 | 66.48  | 58.89  | 3.82  | 3.82  | 19.94  | 19.94  |
| 310 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08  | 23.28  |
| 311 | 133.20 | 107.59 | 32.87 | 6.12  | 40.24  | 43.62  |
| 312 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50  | 59.50  |
| 313 | 133.20 | 85.85  | 24.18 | 6.12  | 40.24  | 43.62  |
| 314 | 133.20 | 85.85  | 24.38 | 6.12  | 40.24  | 43.62  |
| 315 | 133.20 | 19.55  | 12.15 | 6.12  | 40.24  | 43.62  |
| 316 | 133.20 | 19.55  | 12.12 | 6.12  | 40.24  | 43.62  |
| 350 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 351 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 352 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |
| 353 | 41.27  | 8.45   | 1.63  | 0.88  | 15.23  | 10.15  |

## Design Ratio

| Member ID | P     | M <sub>z</sub> | M <sub>y</sub> | V <sub>y</sub> | V <sub>z</sub> | (P,M <sub>z</sub> ,M <sub>y</sub> ) | Worst LC | KL/r  | δ            | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|-------|--------------|--------|
| 1         | 0.054 | 0.375          | 0.033          | 0.023          | 0.003          | 0.403                               | #13      | 0.504 | Not Required | Pass   |
| 2         | 0.005 | 0.267          | 0.104          | 0.068          | 0.019          | 0.343                               | #21      | 0.053 | Not Required | Pass   |
| 3         | 0.007 | 0.376          | 0.119          | 0.037          | 0.051          | 0.494                               | #21      | 0.045 | Not Required | Pass   |
| 4         | 0.007 | 0.373          | 0.062          | 0.038          | 0.010          | 0.438                               | #21      | 0.080 | Not Required | Pass   |
| 5         | 0.007 | 0.233          | 0.037          | 0.037          | 0.011          | 0.272                               | #21      | 0.074 | Not Required | Pass   |
| 6         | 0.003 | 0.495          | 0.153          | 0.051          | 0.058          | 0.649                               | #21      | 0.045 | Not Required | Pass   |
| 7         | 0.003 | 0.306          | 0.011          | 0.049          | 0.004          | 0.317                               | #21      | 0.074 | Not Required | Pass   |
| 8         | 0.005 | 0.068          | 0.134          | 0.034          | 0.012          | 0.177                               | #21      | 0.095 | Not Required | Pass   |
| 9         | 0.022 | 0.039          | 0.062          | 0.002          | 0.002          | 0.107                               | #21      | 0.136 | Not Required | Pass   |
| 10        | 0.004 | 0.480          | 0.058          | 0.048          | 0.008          | 0.526                               | #21      | 0.120 | Not Required | Pass   |
| 11        | 0.003 | 0.065          | 0.138          | 0.035          | 0.012          | 0.181                               | #21      | 0.063 | Not Required | Pass   |
| 12        | 0.006 | 0.394          | 0.149          | 0.089          | 0.025          | 0.511                               | #21      | 0.053 | Not Required | Pass   |
| 13        | 0.004 | 0.142          | 0.072          | 0.044          | 0.010          | 0.211                               | #21      | 0.190 | Not Required | Pass   |
| 14        | 0.009 | 0.139          | 0.061          | 0.042          | 0.009          | 0.181                               | #21      | 0.286 | Not Required | Pass   |
| 15        | 0.004 | 0.043          | 0.025          | 0.018          | 0.007          | 0.065                               | #21      | 0.179 | Not Required | Pass   |
| 16        | 0.005 | 0.042          | 0.019          | 0.018          | 0.006          | 0.057                               | #21      | 0.179 | Not Required | Pass   |
| 50        | 0.248 | 0.009          | 0.004          | 0.002          | 0.001          | 0.260                               | #23      | 0.783 | Not Required | Pass   |
| 51        | 0.049 | 0.005          | 0.014          | 0.001          | 0.001          | 0.063                               | #23      | 0.522 | Not Required | Pass   |
| 52        | 0.088 | 0.009          | 0.004          | 0.001          | 0.000          | 0.099                               | #21      | 0.783 | Not Required | Pass   |
| 53        | 0.017 | 0.005          | 0.015          | 0.001          | 0.001          | 0.033                               | #21      | 0.522 | Not Required | Pass   |
| 101       | 0.066 | 0.454          | 0.003          | 0.028          | 0.000          | 0.479                               | #13      | 0.504 | Not Required | Pass   |
| 102       | 0.007 | 0.414          | 0.157          | 0.097          | 0.026          | 0.541                               | #21      | 0.053 | Not Required | Pass   |
| 103       | 0.003 | 0.542          | 0.169          | 0.055          | 0.068          | 0.712                               | #21      | 0.045 | Not Required | Pass   |
| 104       | 0.004 | 0.542          | 0.056          | 0.055          | 0.007          | 0.600                               | #21      | 0.080 | Not Required | Pass   |
| 105       | 0.003 | 0.336          | 0.032          | 0.054          | 0.012          | 0.369                               | #21      | 0.074 | Not Required | Pass   |
| 106       | 0.004 | 0.540          | 0.166          | 0.054          | 0.068          | 0.707                               | #21      | 0.045 | Not Required | Pass   |
| 107       | 0.003 | 0.335          | 0.034          | 0.054          | 0.013          | 0.371                               | #21      | 0.074 | Not Required | Pass   |

|     |       |       |       |       |       |       |     |       |              |      |
|-----|-------|-------|-------|-------|-------|-------|-----|-------|--------------|------|
| 108 | 0.007 | 0.057 | 0.133 | 0.036 | 0.011 | 0.158 | #21 | 0.095 | Not Required | Pass |
| 109 | 0.028 | 0.040 | 0.049 | 0.001 | 0.000 | 0.102 | #21 | 0.136 | Not Required | Pass |
| 110 | 0.004 | 0.532 | 0.061 | 0.054 | 0.008 | 0.594 | #21 | 0.080 | Not Required | Pass |
| 111 | 0.004 | 0.053 | 0.133 | 0.037 | 0.012 | 0.162 | #21 | 0.095 | Not Required | Pass |
| 112 | 0.007 | 0.408 | 0.158 | 0.096 | 0.026 | 0.532 | #21 | 0.053 | Not Required | Pass |
| 113 | 0.004 | 0.207 | 0.032 | 0.047 | 0.007 | 0.241 | #21 | 0.286 | Not Required | Pass |
| 114 | 0.012 | 0.219 | 0.033 | 0.047 | 0.007 | 0.240 | #21 | 0.286 | Not Required | Pass |
| 115 | 0.060 | 0.357 | 0.198 | 0.039 | 0.018 | 0.495 | #21 | 0.925 | Not Required | Pass |
| 116 | 0.044 | 0.348 | 0.199 | 0.039 | 0.018 | 0.465 | #21 | 0.925 | Not Required | Pass |
| 150 | 0.245 | 0.009 | 0.004 | 0.002 | 0.001 | 0.256 | #23 | 0.783 | Not Required | Pass |
| 151 | 0.049 | 0.005 | 0.014 | 0.001 | 0.001 | 0.063 | #23 | 0.522 | Not Required | Pass |
| 152 | 0.258 | 0.009 | 0.004 | 0.002 | 0.001 | 0.270 | #21 | 0.783 | Not Required | Pass |
| 153 | 0.052 | 0.005 | 0.014 | 0.001 | 0.001 | 0.066 | #21 | 0.522 | Not Required | Pass |
| 201 | 0.066 | 0.454 | 0.003 | 0.028 | 0.000 | 0.479 | #13 | 0.504 | Not Required | Pass |
| 202 | 0.007 | 0.408 | 0.158 | 0.096 | 0.026 | 0.532 | #21 | 0.053 | Not Required | Pass |
| 203 | 0.004 | 0.540 | 0.166 | 0.054 | 0.068 | 0.707 | #21 | 0.045 | Not Required | Pass |
| 204 | 0.004 | 0.532 | 0.061 | 0.054 | 0.008 | 0.594 | #21 | 0.080 | Not Required | Pass |
| 205 | 0.003 | 0.335 | 0.034 | 0.054 | 0.012 | 0.371 | #21 | 0.074 | Not Required | Pass |
| 206 | 0.003 | 0.542 | 0.169 | 0.055 | 0.068 | 0.712 | #21 | 0.045 | Not Required | Pass |
| 207 | 0.003 | 0.336 | 0.032 | 0.054 | 0.012 | 0.369 | #21 | 0.074 | Not Required | Pass |
| 208 | 0.007 | 0.051 | 0.156 | 0.039 | 0.013 | 0.194 | #21 | 0.095 | Not Required | Pass |
| 209 | 0.028 | 0.040 | 0.049 | 0.001 | 0.000 | 0.102 | #21 | 0.136 | Not Required | Pass |
| 210 | 0.004 | 0.542 | 0.056 | 0.055 | 0.007 | 0.600 | #21 | 0.080 | Not Required | Pass |
| 211 | 0.004 | 0.043 | 0.153 | 0.039 | 0.013 | 0.196 | #21 | 0.095 | Not Required | Pass |
| 212 | 0.007 | 0.414 | 0.157 | 0.097 | 0.026 | 0.541 | #21 | 0.053 | Not Required | Pass |
| 213 | 0.004 | 0.207 | 0.032 | 0.047 | 0.007 | 0.241 | #21 | 0.286 | Not Required | Pass |
| 214 | 0.012 | 0.219 | 0.033 | 0.047 | 0.007 | 0.240 | #21 | 0.286 | Not Required | Pass |
| 215 | 0.061 | 0.283 | 0.174 | 0.037 | 0.017 | 0.412 | #21 | 0.925 | Not Required | Pass |
| 216 | 0.042 | 0.264 | 0.171 | 0.036 | 0.017 | 0.370 | #21 | 0.925 | Not Required | Pass |
| 250 | 0.258 | 0.009 | 0.004 | 0.002 | 0.001 | 0.270 | #21 | 0.783 | Not Required | Pass |
| 251 | 0.052 | 0.005 | 0.014 | 0.001 | 0.001 | 0.066 | #21 | 0.522 | Not Required | Pass |
| 252 | 0.245 | 0.009 | 0.004 | 0.002 | 0.001 | 0.256 | #23 | 0.783 | Not Required | Pass |
| 253 | 0.049 | 0.005 | 0.014 | 0.001 | 0.001 | 0.063 | #23 | 0.522 | Not Required | Pass |
| 301 | 0.054 | 0.375 | 0.033 | 0.023 | 0.003 | 0.403 | #13 | 0.504 | Not Required | Pass |
| 302 | 0.006 | 0.394 | 0.149 | 0.089 | 0.025 | 0.511 | #21 | 0.053 | Not Required | Pass |
| 303 | 0.003 | 0.495 | 0.153 | 0.051 | 0.058 | 0.649 | #21 | 0.045 | Not Required | Pass |
| 304 | 0.004 | 0.480 | 0.058 | 0.048 | 0.008 | 0.526 | #21 | 0.120 | Not Required | Pass |
| 305 | 0.003 | 0.306 | 0.011 | 0.049 | 0.004 | 0.317 | #21 | 0.074 | Not Required | Pass |
| 306 | 0.007 | 0.376 | 0.119 | 0.037 | 0.051 | 0.494 | #21 | 0.045 | Not Required | Pass |
| 307 | 0.007 | 0.233 | 0.037 | 0.037 | 0.011 | 0.272 | #21 | 0.074 | Not Required | Pass |
| 308 | 0.005 | 0.042 | 0.019 | 0.018 | 0.006 | 0.057 | #21 | 0.268 | Not Required | Pass |
| 309 | 0.022 | 0.039 | 0.062 | 0.002 | 0.002 | 0.107 | #21 | 0.136 | Not Required | Pass |
| 310 | 0.007 | 0.373 | 0.062 | 0.038 | 0.010 | 0.438 | #21 | 0.080 | Not Required | Pass |
| 311 | 0.004 | 0.043 | 0.025 | 0.018 | 0.007 | 0.065 | #21 | 0.179 | Not Required | Pass |
| 312 | 0.005 | 0.267 | 0.104 | 0.068 | 0.019 | 0.343 | #21 | 0.053 | Not Required | Pass |
| 313 | 0.004 | 0.142 | 0.072 | 0.044 | 0.010 | 0.211 | #21 | 0.190 | Not Required | Pass |
| 314 | 0.009 | 0.139 | 0.061 | 0.042 | 0.009 | 0.181 | #21 | 0.286 | Not Required | Pass |
| 315 | 0.060 | 0.367 | 0.198 | 0.035 | 0.018 | 0.506 | #21 | 0.616 | Not Required | Pass |
| 316 | 0.044 | 0.363 | 0.199 | 0.034 | 0.018 | 0.480 | #21 | 0.925 | Not Required | Pass |
| 350 | 0.088 | 0.009 | 0.004 | 0.001 | 0.000 | 0.099 | #21 | 0.783 | Not Required | Pass |
| 351 | 0.017 | 0.005 | 0.015 | 0.001 | 0.001 | 0.033 | #21 | 0.522 | Not Required | Pass |
| 352 | 0.248 | 0.009 | 0.004 | 0.002 | 0.001 | 0.260 | #23 | 0.783 | Not Required | Pass |

|     |       |       |       |       |       |       |     |       |              |      |
|-----|-------|-------|-------|-------|-------|-------|-----|-------|--------------|------|
| 353 | 0.049 | 0.005 | 0.014 | 0.001 | 0.001 | 0.063 | #23 | 0.522 | Not Required | Pass |
|-----|-------|-------|-------|-------|-------|-------|-----|-------|--------------|------|

## Definitions

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|                 |                                                           |
|-----------------|-----------------------------------------------------------|
| $\Phi_t$        | Safety factor for tensile                                 |
| $\Phi_c$        | Safety factor for compression                             |
| $\Phi_b$        | Safety factor for flexure                                 |
| $\Phi_v$        | Safety factor for shear                                   |
| E               | Modulus of elasticity                                     |
| $F_y$           | Specified minimum yield stress                            |
| $F_u$           | Specified minimum tensile strength                        |
| A               | Cross-sectional area                                      |
| J               | Torsional constant                                        |
| $I_{yp}$        | Moment of inertia about the Y axes                        |
| $I_{zp}$        | Moment of inertia about the Z axes                        |
| $I_w$           | Warping constant                                          |
| $S_{yp}$        | Plastic section modulus about the Y axis                  |
| $S_{zp}$        | Plastic section modulus about the Z axis                  |
| KL              | Effective length                                          |
| $C_b$           | Buckling modification factor (from all load combinations) |
| $L_b$           | Length between braced points                              |
| LST             | Limited slenderness for tension                           |
| LSC             | Limited slenderness for compression                       |
| LD              | Limited deflection                                        |
| $P_n$           | Nominal axial strength (tension/compression)              |
| $M_n$           | Nominal flexural strength (about Z/Y axis)                |
| $V_n$           | Nominal shear strength (along Z/Y axis)                   |
| P               | Design ratio in case of axial force                       |
| $M_z$           | Design ratio in case of bending about Z axis              |
| $M_y$           | Design ratio in case of bending about Y axis              |
| $V_y$           | Design ratio in case of shear along Y axis                |
| $V_z$           | Design ratio in case of shear along Z axis                |
| $(P, M_z, M_y)$ | Design ratio in case of axial force and bending action    |
| KL/r            | Design ratio in case of section slenderness               |
| $\delta$        | Design ratio in case of member deflection                 |
| OK              | Capacity is provided                                      |
| NG              | Capacity is not provided                                  |





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

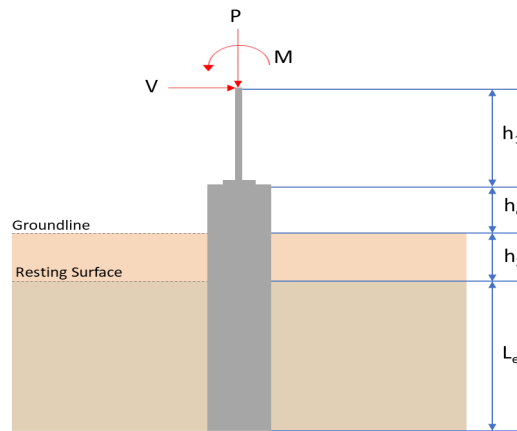
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 5.75$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

| Load Component | ASD    | LRFD   |
|----------------|--------|--------|
| $P$ (kip)      | 6.200  | 9.748  |
| $V_x$ (kip)    | -1.570 | -2.627 |
| $V_z$ (kip)    | 0.218  | 0.337  |
| $M_x$ (kipft)  | 0.749  | 1.164  |
| $M_z$ (kipft)  | 18.360 | 31.216 |

### Material Properties

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

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

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

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

$$H_o = -0.25 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(18.36 \text{ kipft}) + ((-1.57 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.9236 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.355 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.218 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.034713 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.749 \text{ kipft}) + ((0.218 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11927 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.4461 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.355 \text{ ft}), (2.4461 \text{ ft})]$$

$$L_{e,req} = 5.355 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.75 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.355 \text{ ft})}{(5.75 \text{ ft})}$$

$$\text{Ratio} = 0.9313$$

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

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(6.2 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.3875 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.3875 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.19375$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(5.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.4375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.25 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 2.9236 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (2.9236 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (2.9236 \text{ kipft/ft})) + (4 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9516 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.9236 \text{ kipft/ft})) + (3 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 \times [(3 \times (2.9236 \text{ kipft/ft})) + (2 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = 0.20966 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (2.9236 \text{ kipft/ft})) + ((-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.80024 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9516 \text{ ft})}{2}$$

$$p_a = 0.29637 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.20966 \text{ kip/ft}^2)}{(0.29637 \text{ kip/ft}^2)}$$

$$Ratio = 0.70741$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.75 \text{ ft})$$

$$p_s = 0.8625 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.80024 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$Ratio = 0.92781$$

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

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

#### Considering z-direction:

$H_o = 0.034713 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.11927 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.11927 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (0.034713 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (0.11927 \text{ kipft/ft})) + (4 \times (0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.086 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.11927 \text{ kipft/ft})) + (3 \times (0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 [(3 \times (0.11927 \text{ kipft/ft})) + (2 \times (0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = 0.034686 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.11927 \text{ kipft/ft})) + ((0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.079511 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.086 \text{ ft})}{2}$$

$$p_a = 0.30645 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.034686 \text{ kip/ft}^2)}{(0.30645 \text{ kip/ft}^2)}$$

$$Ratio = 0.11318$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.75 \text{ ft})$$

$$p_s = 0.8625 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

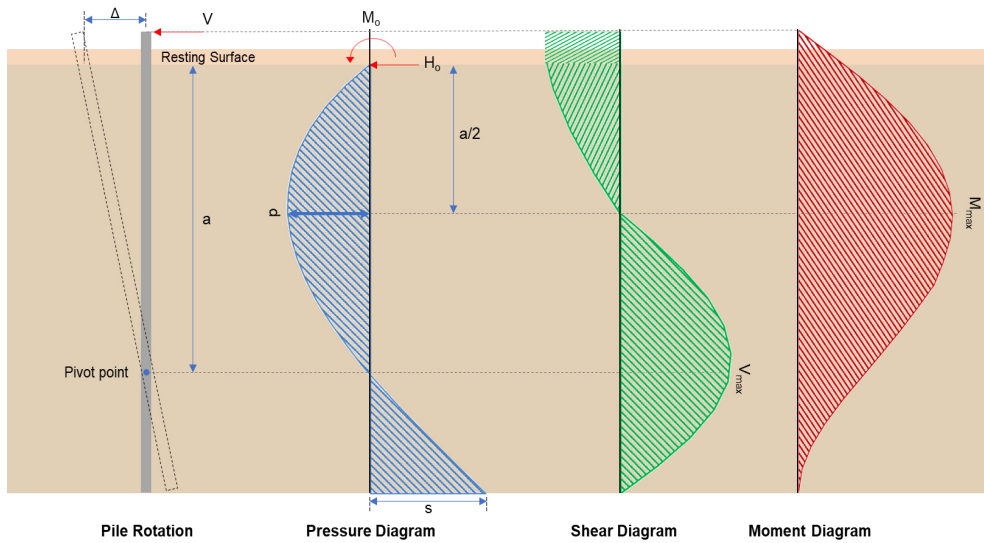
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.079511 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$Ratio = 0.092186$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-2.627 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.41831 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(31.216 \text{ kipft}) + ((-2.627 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9707 \text{ kipft/ft}$$

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

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

$$E = \frac{(4.9707 \text{ kipft/ft})}{(-0.41831 \text{ kip/ft})}$$

$$E = 11.883 \text{ ft}$$

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

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

$$a = \frac{(4 \times (4.9707 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (4.9707 \text{ kipft/ft})) + (4 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = \frac{(-0.41831 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (4.9707 \text{ kip/ft})) + (4 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9502 \text{ ft}$$

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

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

$$V_{max} = ((-0.41831 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9502 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9502 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.2238 \text{ kip}$$

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

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

$$M_{max} = ((-0.41831 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[ \left( \frac{(11.883 \text{ ft})}{(5.75 \text{ ft})} + \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 19.893 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.337 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.053662 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.164 \text{ kipft}) + ((0.337 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.18535 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.18535 \text{ kipft/ft})}{(0.053662 \text{ kip/ft})}$$

$$E = 3.454 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.18535 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (0.053662 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (0.18535 \text{ kipft/ft})) + (4 \times (0.053662 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.0854 \text{ ft}$$

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

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

$$V_{max} = ((0.053662 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.454 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.0854 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.454 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.0854 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.37079 \text{ kip}$$

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

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

$$M_{max} = ((0.053662 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[ \left( \frac{(3.454 \text{ ft})}{(5.75 \text{ ft})} + \frac{(4.0854 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.454 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.0854 \text{ ft})}{(2 \times (5.75 \text{ ft}))} \right)^3 \right] + \left[ \left( \frac{3 \times (3.454 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.0854 \text{ ft})}{(2 \times (5.75 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 0.95564 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(9.748 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.272 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.272 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                    |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = 0.96556</math></p> <p><math>s_{rebar} = \text{Min spacing of reinforcement,}</math></p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties}</math> - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <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><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(9.748 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0036439$                                                                                                                                                                                                                                                                                                                                       | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 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> $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <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  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 9.748 \text{ kip} \rightarrow 9748 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(9748 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.79 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.79 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.79 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.79 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.94 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 7.2238 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.2238 \text{ kip})}{(110.94 \text{ kip})}$$

$$Ratio = 0.065113$$

**Considering z-direction:**

$V_{max} = 0.37079 \text{ kip}$  - Maximum shear force in the z-direction,  
*Ratio* - Capacity

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

$$Ratio = \frac{(0.37079 \text{ kip})}{(110.94 \text{ kip})}$$

$$Ratio = 0.0033422$$

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

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

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - 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

$\phi M_{n,2}$

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

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

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

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:**

$M_{max} = 19.893 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$Ratio = \frac{(19.893 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0797$$

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

**Considering z-direction:**

$M_{max} = 0.95564 \text{ kipft}$  - Maximum moment in the z-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(0.95564 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0038287$$

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

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

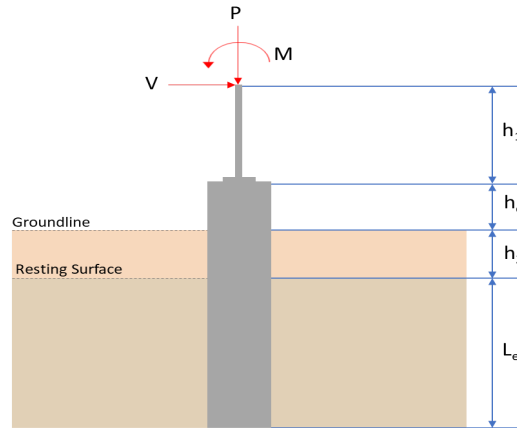
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 5.75$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

| Load Component | ASD    | LRFD   |
|----------------|--------|--------|
| $P$ (kip)      | 6.200  | 9.748  |
| $V_x$ (kip)    | -1.570 | -2.627 |
| $V_z$ (kip)    | -0.218 | -0.336 |
| $M_x$ (kipft)  | -0.749 | -1.164 |
| $M_z$ (kipft)  | 18.360 | 31.216 |

### Material Properties

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

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

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

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

$$H_o = -0.25 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(18.36 \text{ kipft}) + ((-1.57 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.9236 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.355 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.218 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.034713 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.749 \text{ kipft}) + ((-0.218 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11927 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.7967 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.355 \text{ ft}), (1.7967 \text{ ft})]$$

$$L_{e,req} = 5.355 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.75 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.355 \text{ ft})}{(5.75 \text{ ft})}$$

$$\text{Ratio} = 0.9313$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(6.2 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.3875 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.3875 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.19375$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(5.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.4375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.25 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 2.9236 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (2.9236 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (2.9236 \text{ kipft/ft})) + (4 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9516 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.9236 \text{ kipft/ft})) + (3 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 \times [(3 \times (2.9236 \text{ kipft/ft})) + (2 \times (-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = 0.20966 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (2.9236 \text{ kipft/ft})) + ((-0.25 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.80024 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9516 \text{ ft})}{2}$$

$$p_a = 0.29637 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20966 \text{ kip/ft}^2)}{(0.29637 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.70741$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.75 \text{ ft})$$

$$p_s = 0.8625 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.80024 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92781$$

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

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

#### Considering z-direction:

$H_o = -0.034713 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.11927 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.11927 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.034713 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (0.11927 \text{ kipft/ft})) + (4 \times (-0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.086 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11927 \text{ kipft/ft})) + (3 \times (-0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 \times [(3 \times (0.11927 \text{ kipft/ft})) + (2 \times (-0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = -0.0081198 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.11927 \text{ kipft/ft})) + ((-0.034713 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.0070654 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.086 \text{ ft})}{2}$$

$$p_a = 0.30645 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0081198 \text{ kip/ft}^2)}{(0.30645 \text{ kip/ft}^2)}$$

$$Ratio = -0.026496$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.75 \text{ ft})$$

$$p_s = 0.8625 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

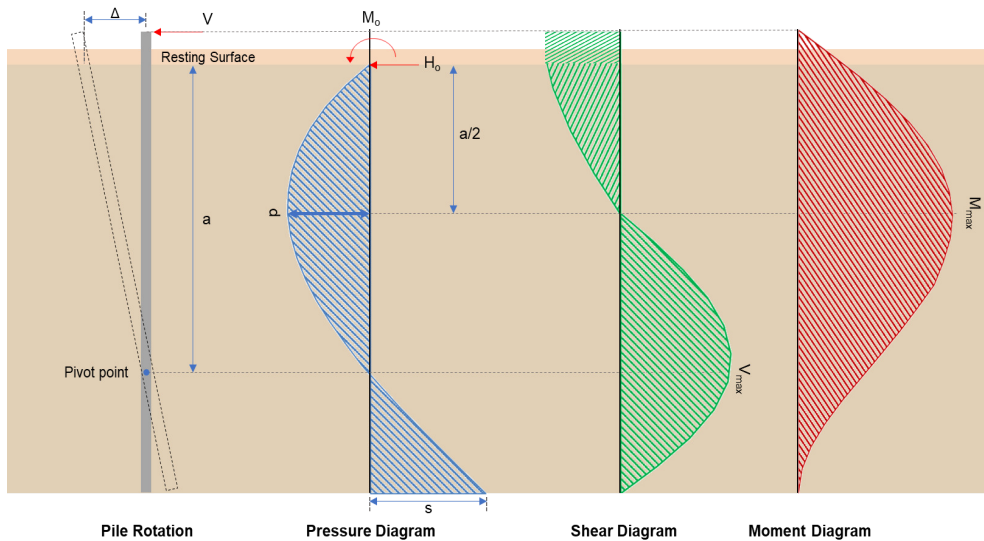
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0070654 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$Ratio = 0.0081917$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-2.627 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.41831 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(31.216 \text{ kipft}) + ((-2.627 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9707 \text{ kipft/ft}$$

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

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

$$E = \frac{(4.9707 \text{ kipft/ft})}{(-0.41831 \text{ kip/ft})}$$

$$E = 11.883 \text{ ft}$$

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

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

$$a = \frac{(4 \times (4.9707 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (4.9707 \text{ kipft/ft})) + (4 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = \frac{(-0.41831 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (4.9707 \text{ kip/ft})) + (4 \times (-0.41831 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9502 \text{ ft}$$

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

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

$$V_{max} = ((-0.41831 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9502 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9502 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.2238 \text{ kip}$$

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

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

$$M_{max} = ((-0.41831 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[ \left( \frac{(11.883 \text{ ft})}{(5.75 \text{ ft})} + \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (11.883 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9502 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 19.893 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.336 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.053503 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.164 \text{ kipft}) + ((-0.336 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.18535 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.18535 \text{ kipft/ft})}{(-0.053503 \text{ kip/ft})}$$

$$E = 3.4643 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.18535 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.053503 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (0.18535 \text{ kipft/ft})) + (4 \times (-0.053503 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 4.085 \text{ ft}$$

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

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

$$V_{max} = ((-0.053503 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.4643 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.085 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.4643 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.085 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.37036 \text{ kip}$$

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

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

$$M_{max} = ((-0.053503 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[ \left( \frac{(3.4643 \text{ ft})}{(5.75 \text{ ft})} + \frac{(4.085 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.4643 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.085 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.4643 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.085 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.95473 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(9.748 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.272 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.272 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = 0.96556</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <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> <p style="text-align: center;"><math>\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \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></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(9.748 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0036439</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                            | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>,</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p> |                                                    |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 9.748 \text{ kip} \rightarrow 9748 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(9748 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.79 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.79 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.79 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.79 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.94 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 7.2238 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.2238 \text{ kip})}{(110.94 \text{ kip})}$$

$$Ratio = 0.065113$$

**Considering z-direction:**

$V_{max} = 0.37036 \text{ kip}$  - Maximum shear force in the z-direction,  
*Ratio* - Capacity

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

$$Ratio = \frac{(0.37036 \text{ kip})}{(110.94 \text{ kip})}$$

$$Ratio = 0.0033383$$

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

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

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - 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:**

$M_{max} = 19.893 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$Ratio = \frac{(19.893 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0797$$

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

**Considering z-direction:**

$M_{max} = 0.95473 \text{ kipft}$  - Maximum moment in the z-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(0.95473 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.003825$$

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

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

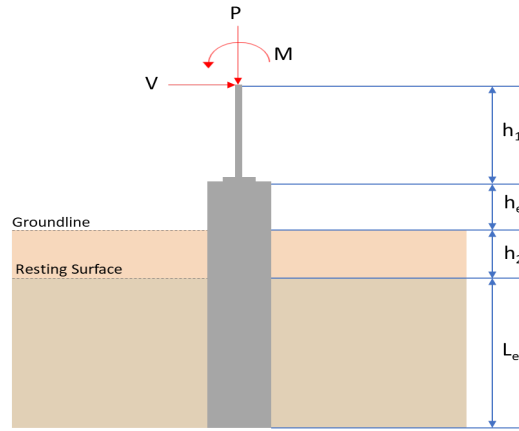
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 6$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

| Load Component | ASD    | LRFD   |
|----------------|--------|--------|
| $P$ (kip)      | 7.555  | 11.911 |
| $V_x$ (kip)    | -1.875 | -3.132 |
| $V_z$ (kip)    | -0.015 | -0.025 |
| $M_x$ (kipft)  | -0.053 | -0.087 |
| $M_z$ (kipft)  | 22.204 | 37.854 |

### Material Properties

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

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

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.875 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.29857 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(22.204 \text{ kipft}) + ((-1.875 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.5357 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.6612 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.015 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0023885 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.053 \text{ kipft}) + ((-0.015 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0084395 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.82288 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.6612 \text{ ft}), (0.82288 \text{ ft})]$$

$$L_{e,req} = 5.661 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.661 \text{ ft})}{(6 \text{ ft})}$$

$$\text{Ratio} = 0.9435$$

Status: **PASS**  
Ratio: **0.940**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(7.555 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.47219 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.47219 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.23609$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.5$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.29857 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 3.5357 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (3.5357 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (3.5357 \text{ kipft/ft})) + (4 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1262 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.5357 \text{ kipft/ft})) + (3 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (3.5357 \text{ kipft/ft})) + (2 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.22804 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (3.5357 \text{ kipft/ft})) + ((-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.88 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1262 \text{ ft})}{2}$$

$$p_a = 0.30947 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22804 \text{ kip/ft}^2)}{(0.30947 \text{ kip/ft}^2)}$$

$$Ratio = 0.73687$$

$p_s$  - 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

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

$$Ratio = \frac{(0.88 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.97777$$

Status: **PASS**  
Ratio: **0.740**

Status: **PASS**  
Ratio: **0.980**

#### Considering z-direction:

$H_o = -0.0023885 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.0084395 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.0084395 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.0023885 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.0084395 \text{ kipft/ft})) + (4 \times (-0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2655 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.0084395 \text{ kipft/ft})) + (3 \times (-0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (0.0084395 \text{ kipft/ft})) + (2 \times (-0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = -0.00053142 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.0084395 \text{ kipft/ft})) + ((-0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.00042463 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2655 \text{ ft})}{2}$$

$$p_a = 0.31991 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.00053142 \text{ kip/ft}^2)}{(0.31991 \text{ kip/ft}^2)}$$

$$Ratio = -0.0016611$$

$p_s$  - 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

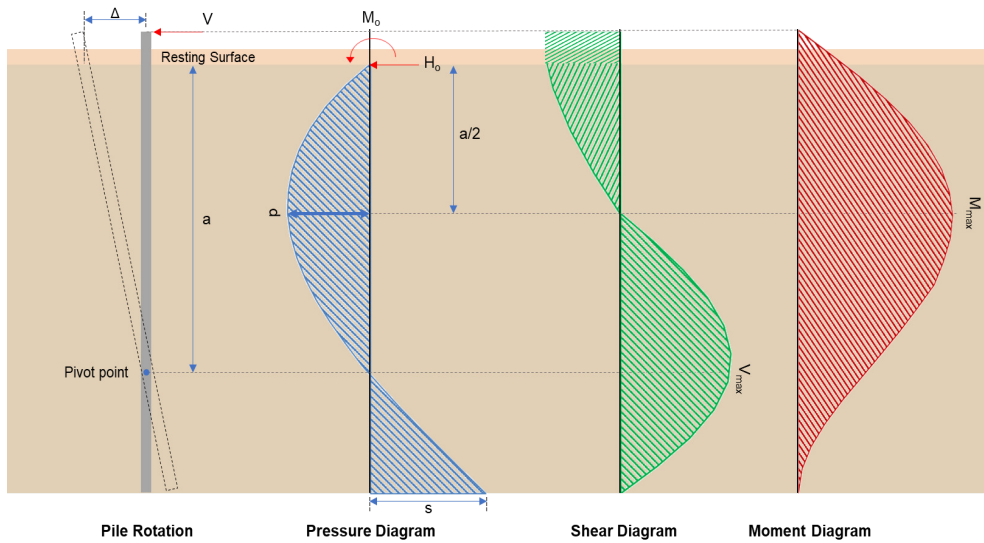
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.00042463 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.00047181$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.132 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49873 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(37.854 \text{ kipft}) + ((-3.132 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.0277 \text{ kipft/ft}$$

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

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

$$E = \frac{(6.0277 \text{ kipft/ft})}{(-0.49873 \text{ kip/ft})}$$

$$E = 12.086 \text{ ft}$$

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

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

$$a = \frac{(4 \times (6.0277 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (6.0277 \text{ kipft/ft})) + (4 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = \frac{(-0.49873 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (6.0277 \text{ kipft/ft})) + (4 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1243 \text{ ft}$$

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

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

$$V_{max} = ((-0.49873 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1243 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1243 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.4278 \text{ kip}$$

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

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

$$M_{max} = ((-0.49873 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[ \left( \frac{(12.086 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 24.195 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.025 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0039809 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.087 \text{ kipft}) + ((-0.025 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.013854 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.013854 \text{ kipft/ft})}{(-0.0039809 \text{ kip/ft})}$$

$$E = 3.48 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.013854 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.0039809 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.013854 \text{ kipft/ft})) + (4 \times (-0.0039809 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2674 \text{ ft}$$

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

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

$$V_{max} = ((-0.0039809 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.2674 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.2674 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.026929 \text{ kip}$$

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

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

$$M_{max} = ((-0.0039809 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[ \left( \frac{(3.48 \text{ ft})}{(6 \text{ ft})} + \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.072246 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(11.911 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.2 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.2 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = 0.96556</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <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> <p style="text-align: center;"><math>\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \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></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.911 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0044524</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                           | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>,</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p> |                                                    |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.911 \text{ kip} \rightarrow 11911 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(11911 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.07 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.07 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.07 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.07 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.13 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 8.4278 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(8.4278 \text{ kip})}{(111.13 \text{ kip})}$$

$$Ratio = 0.075839$$

**Considering z-direction:**

$V_{max} = 0.026929 \text{ kip}$  - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.026929 \text{ kip})}{(111.13 \text{ kip})}$$

$$Ratio = 0.00024232$$

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

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

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - 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:**

$M_{max} = 24.195 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(24.195 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.096934$$

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

**Considering z-direction:**

$M_{max} = 0.072246 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.072246 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00028945$$

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

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

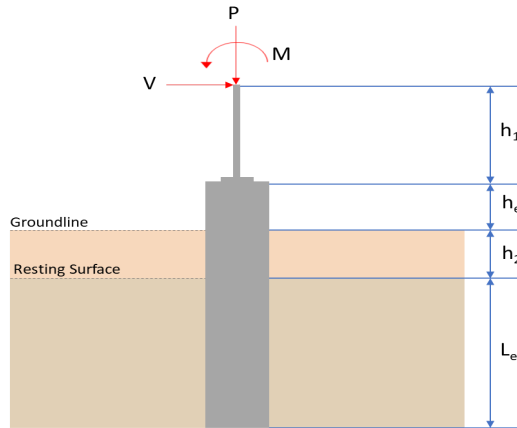
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 6$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

| Load Component | ASD    | LRFD   |
|----------------|--------|--------|
| $P$ (kip)      | 7.555  | 11.910 |
| $V_x$ (kip)    | -1.875 | -3.132 |
| $V_z$ (kip)    | 0.015  | 0.025  |
| $M_x$ (kipft)  | 0.053  | 0.087  |
| $M_z$ (kipft)  | 22.204 | 37.854 |

### Material Properties

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

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

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.875 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.29857 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(22.204 \text{ kipft}) + ((-1.875 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.5357 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.6612 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.015 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0023885 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.053 \text{ kipft}) + ((0.015 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0084395 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.93171 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.6612 \text{ ft}), (0.93171 \text{ ft})]$$

$$L_{e,req} = 5.661 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.661 \text{ ft})}{(6 \text{ ft})}$$

$$\text{Ratio} = 0.9435$$

Status: **PASS**  
Ratio: **0.940**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(7.555 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.47219 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.47219 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.23609$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.5$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.29857 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 3.5357 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (3.5357 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (3.5357 \text{ kipft/ft})) + (4 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1262 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.5357 \text{ kipft/ft})) + (3 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (3.5357 \text{ kipft/ft})) + (2 \times (-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.22804 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (3.5357 \text{ kipft/ft})) + ((-0.29857 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.88 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1262 \text{ ft})}{2}$$

$$p_a = 0.30947 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22804 \text{ kip/ft}^2)}{(0.30947 \text{ kip/ft}^2)}$$

$$Ratio = 0.73687$$

$p_s$  - 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

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

$$Ratio = \frac{(0.88 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.97777$$

Status: **PASS**  
Ratio: **0.740**

Status: **PASS**  
Ratio: **0.980**

#### Considering z-direction:

$H_o = 0.0023885 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.0084395 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.0084395 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (0.0023885 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.0084395 \text{ kipft/ft})) + (4 \times (0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2655 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0084395 \text{ kipft/ft})) + (3 \times (0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (0.0084395 \text{ kipft/ft})) + (2 \times (0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.0022735 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.0084395 \text{ kipft/ft})) + ((0.0023885 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.0052017 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2655 \text{ ft})}{2}$$

$$p_a = 0.31991 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0022735 \text{ kip/ft}^2)}{(0.31991 \text{ kip/ft}^2)}$$

$$Ratio = 0.0071066$$

$p_s$  - 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

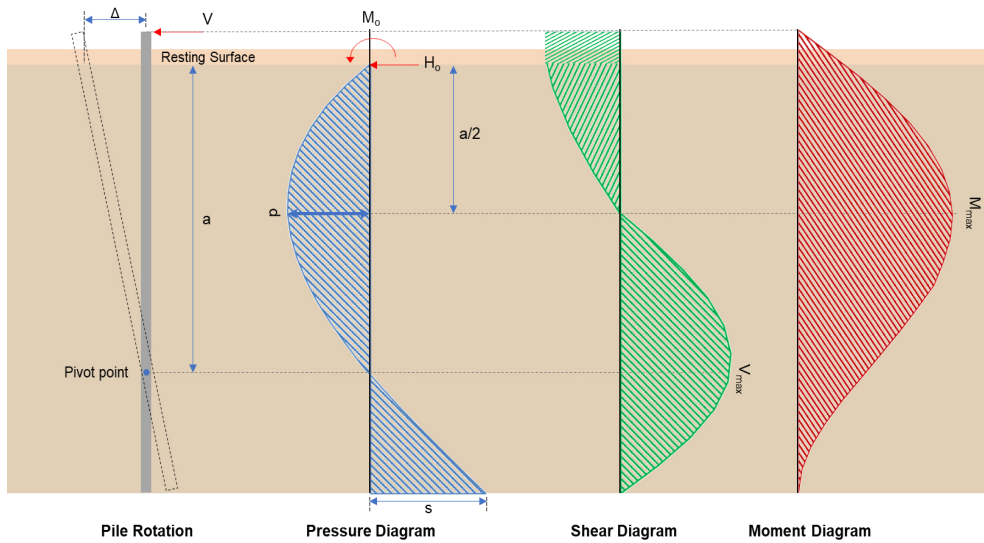
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0052017 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.0057797$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.132 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49873 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(37.854 \text{ kipft}) + ((-3.132 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.0277 \text{ kipft/ft}$$

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

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

$$E = \frac{(6.0277 \text{ kipft/ft})}{(-0.49873 \text{ kip/ft})}$$

$$E = 12.086 \text{ ft}$$

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

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

$$a = \frac{(4 \times (6.0277 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (6.0277 \text{ kipft/ft})) + (4 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = \frac{(-0.49873 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (6.0277 \text{ kip/ft})) + (4 \times (-0.49873 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1243 \text{ ft}$$

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

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

$$V_{max} = ((-0.49873 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1243 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1243 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.4278 \text{ kip}$$

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

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

$$M_{max} = ((-0.49873 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[ \left( \frac{(12.086 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.086 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.1243 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 24.195 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.025 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0039809 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.087 \text{ kipft}) + ((0.025 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.013854 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.013854 \text{ kipft/ft})}{(0.0039809 \text{ kip/ft})}$$

$$E = 3.48 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.013854 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (0.0039809 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.013854 \text{ kipft/ft})) + (4 \times (0.0039809 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.2674 \text{ ft}$$

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

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

$$V_{max} = ((0.0039809 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.2674 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.2674 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.026929 \text{ kip}$$

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

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

$$M_{max} = ((0.0039809 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[ \left( \frac{(3.48 \text{ ft})}{(6 \text{ ft})} + \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left( \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.48 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left( \frac{(4.2674 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.072246 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(11.91 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.2 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.2 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

|                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>       | <p style="text-align: center;"><math>Ratio = 0.96556</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <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> <p style="text-align: center;"><math>\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \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></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.91 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.004452</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                             | <p>Status: <b>PASS</b><br/>Ratio: <b>0.000</b></p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 48 \text{ in}</math> - Effective width,<br/><math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>,</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p> |                                                    |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.91 \text{ kip} \rightarrow 11910 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(11910 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.07 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.07 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.07 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.07 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.13 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 8.4278 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(8.4278 \text{ kip})}{(111.13 \text{ kip})}$$

$$Ratio = 0.075839$$

**Considering z-direction:**

$V_{max} = 0.026929 \text{ kip}$  - Maximum shear force in the z-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(0.026929 \text{ kip})}{(111.13 \text{ kip})}$$

$$Ratio = 0.00024232$$

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

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

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

$S_m$  - Section modulus

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

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

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

$\lambda = 1$  - 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:**

$M_{max} = 24.195 \text{ kipft}$  - Maximum moment in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(24.195 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.096934$$

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

**Considering z-direction:**

$M_{max} = 0.072246 \text{ kipft}$  - Maximum moment in the z-direction,

$Ratio$  - Capacity

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

$$\text{Ratio} = \frac{(0.072246 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00028945$$

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