# Project Details

**Project Name:** Bzn Trail III - V1JB

**Location:** 31842 Frontage Rd, Bozeman, MT 59715, USA

**Unique ID:** 4P-22.5-10TOP-HD-45-L-5Hx13W-STRUTS-J2K3

**Dealer:** ______________________________

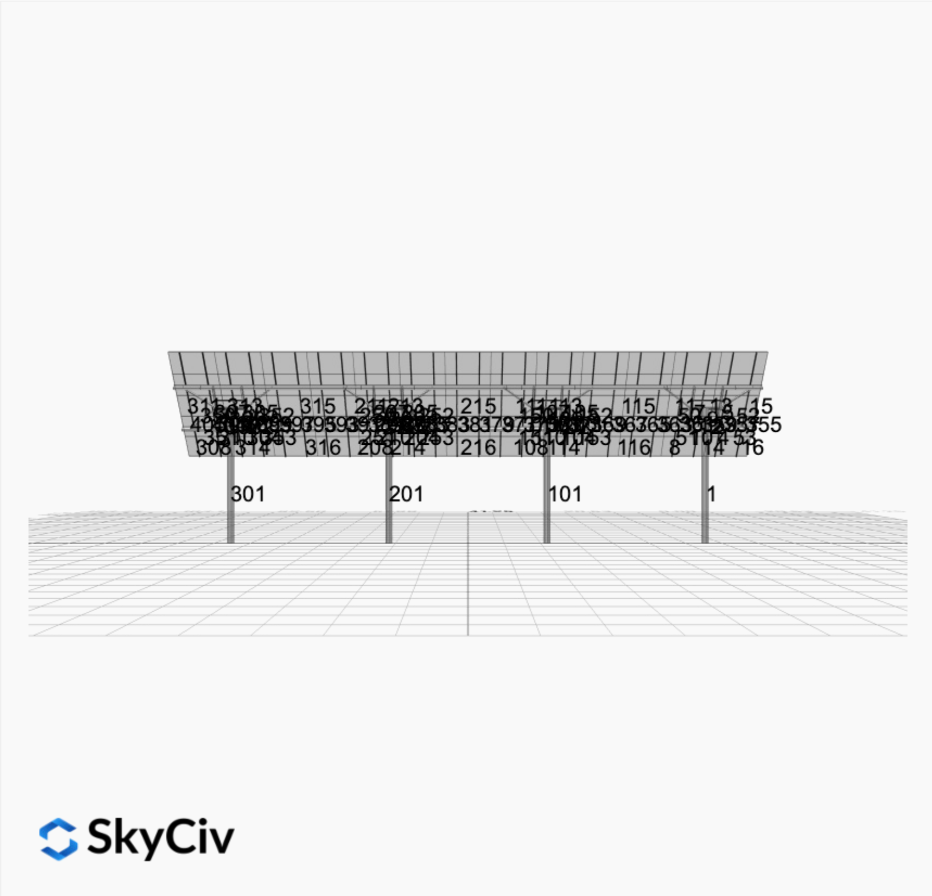
**Date:** Fri Apr 25 2025

**Number of Modules:** 65

**Number of Poles:** 4

**Date Sold:**

______________________________




| | |
|---|---|
| **Array Dimensions N/S** | 18.79 ft |
| **Array Dimensions E/W** | 82.44 ft |
| **Winter Tilt Angle** | 50 |
| **Front Edge Clearance** | 12 ft |

### MT Solar Bill of Materials (4P-22.5-10TOP-HD-45-L-5Hx13W-STRUTS-J2K3)

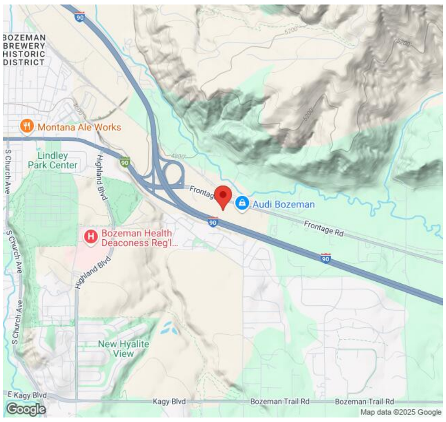
| Part | Short Description | BOM Qty |
|---|---|---|
| MTS-PC-10 | 10IN Pole Cap Assembly | 4 |
| MTS-HF-HD | H-Frame Assembly-HD | 4 |
| MTS-HD-Wing-45 | 45IN HD Wing | 4 |
| MTS-HD-Splice-90 | 90IN HD Splice | 12 |
| MTS-CLAMP-ANGLE-4PK | Angle Clamp | 13 |

### Rail Bill of Materials

| Part | Qty |
|---|---|
| Rails (226in) | 26 |
| Rail Attachment | 104 |

| Part | Qty |
| --- | --- |
| Module Mid Clamp | 104 |
| Module End Clamp | 52 |
| Ground Lug | 13 |

# Site Details:




**Site Address:** 31842 Frontage Rd, Bozeman, MT 59715, USA

### Array Specification

| | |
|---|---|
| **Duty Classification:** | HD |
| **Module Width:** | 44.60 in |
| **Module Length:** | 75.10in |
| **Number of Rows:** | 5 |
| **Number of Columns:** | 13 |
| **Total Number of Modules:** | 65 |
| **Winter Tilt Angle:** | 50 |
| **Front Edge Clearance:** | 12 |
| **Total Array Height at Tilt:** | 26.40 ft |
| **Total Frame Length:** | 82.50 ft |
| **Module Info/Notes:** | Aptos DNA-120-BF10-460W |
| **Array Dimensions N/S:** | 18.79 ft |
| **Array Dimensions E/W:** | 82.44 ft |
| **Rail Length:** | 225.50 in |
| **Rail Spacing:** | 3.17 ft |

### Support Specifications

| | |
|---|---|
| **Pole Size:** | 10in Pipe Sch 80 |
| **Pole Length above Grade:** | 19.20 ft |
| **Number of Poles:** | 4 |
| **Pole Spacing:** | 22.5 ft |

### Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 9.50 ft<br>Pile 2: 9.75 ft<br>Pile 3: 9.75 ft<br>Pile 4: 9.50 ft |
| **Foundation Volume:** | 22.815 $y^3$ |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 31842 Frontage Rd, Bozeman, MT 59715, USA |
| **Wind Speed:** | 115 mph |

| | |
|---|---|
| **Snow Load:** | 51 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


```
{"wind_speed_override":115,"snow_load_override":51,"direct_snow_load":false,"add_angle_brace":true,"product_type":"Beam","designer_name":"Thomas","designer_email":"thomas.burney@onsiteenergyinc.com","designer_phone":"","project_id":"Bzn Trail III - V1JB","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_info":"Aptos DNA-120-BF10-460W","module_width":44.6,"module_length":75.1,"number_rows":"5","number_columns":13,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":50,"ground_clearance":12,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}
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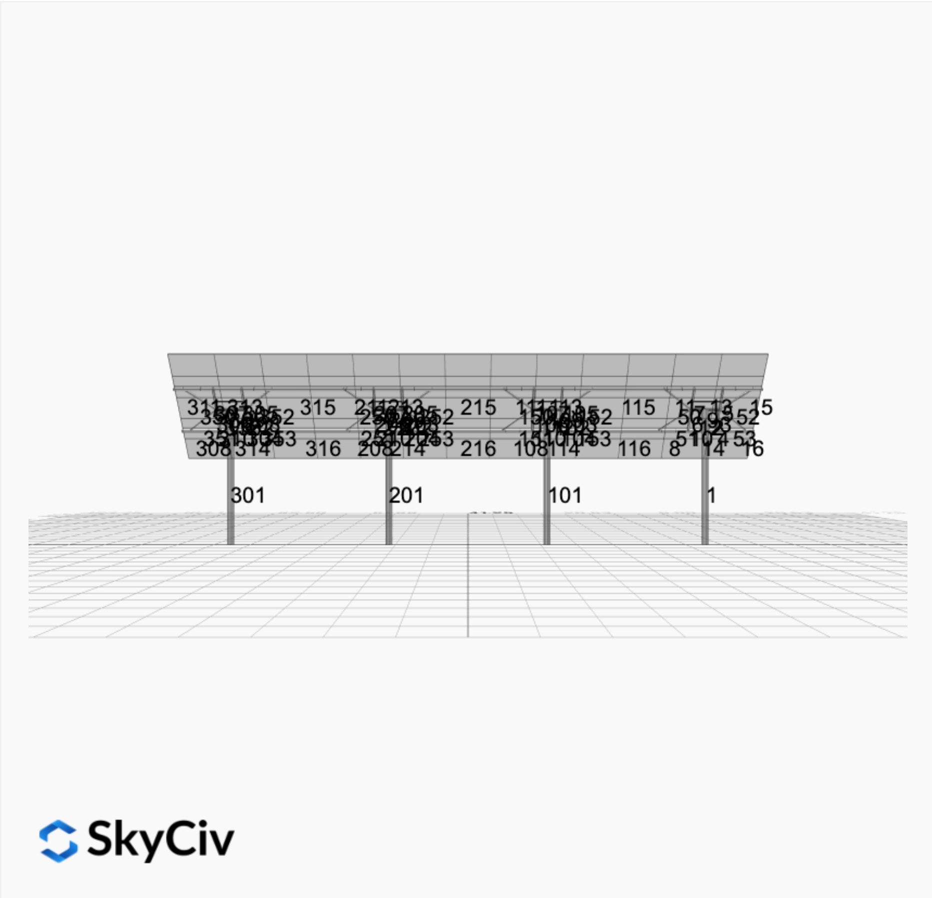
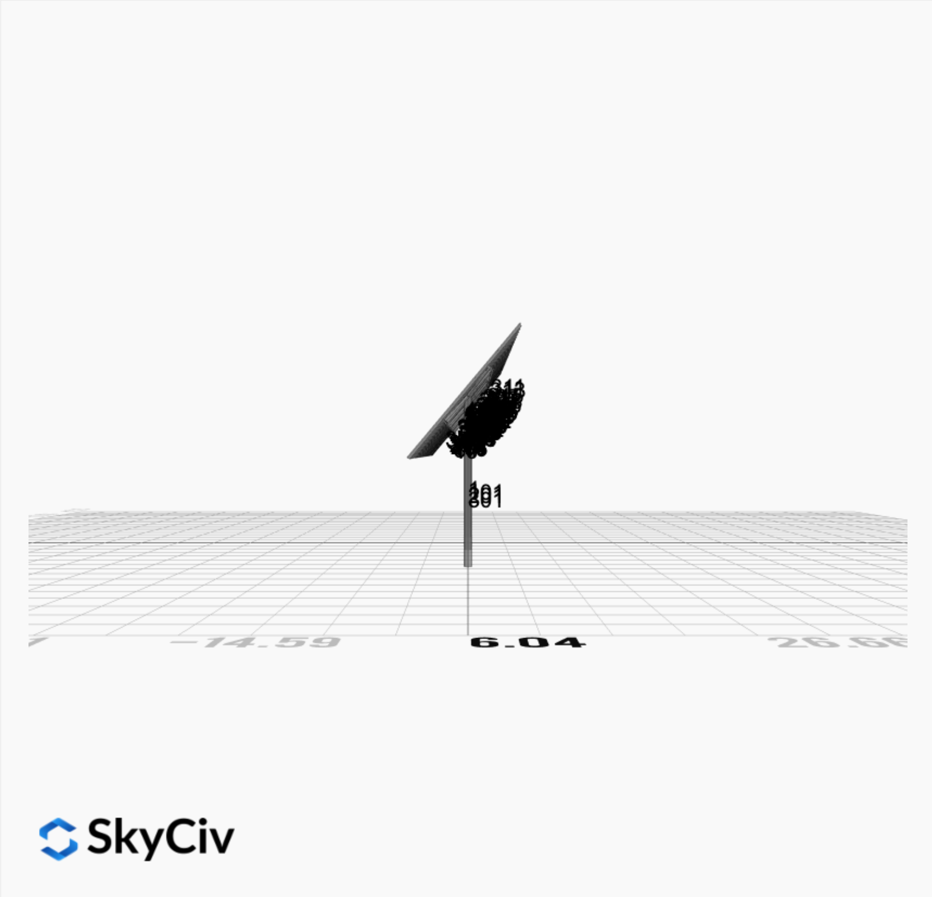
**Design Notes:**

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation 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)

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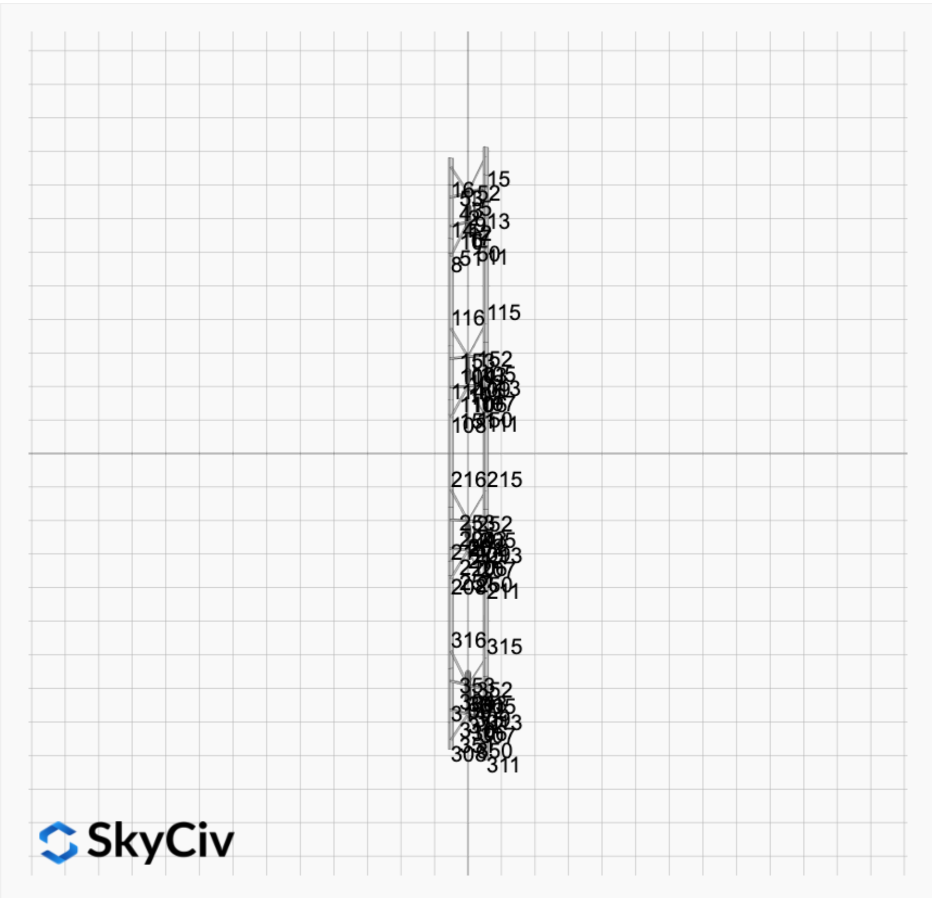
6.04
SkyCiv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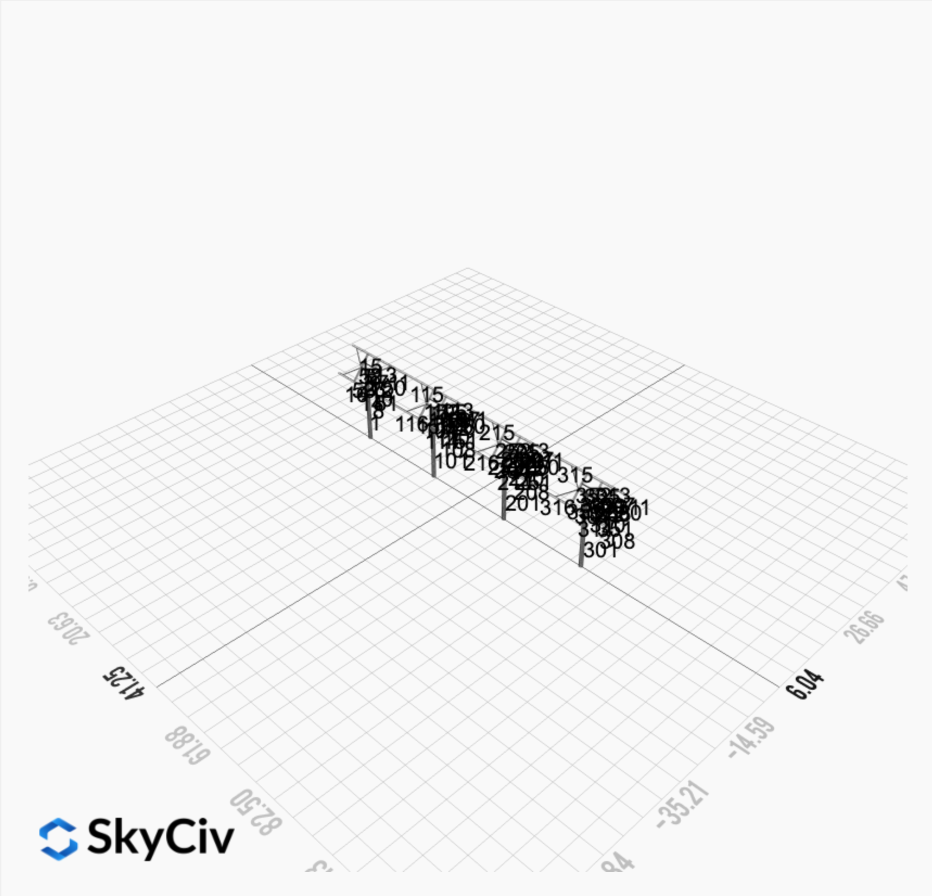
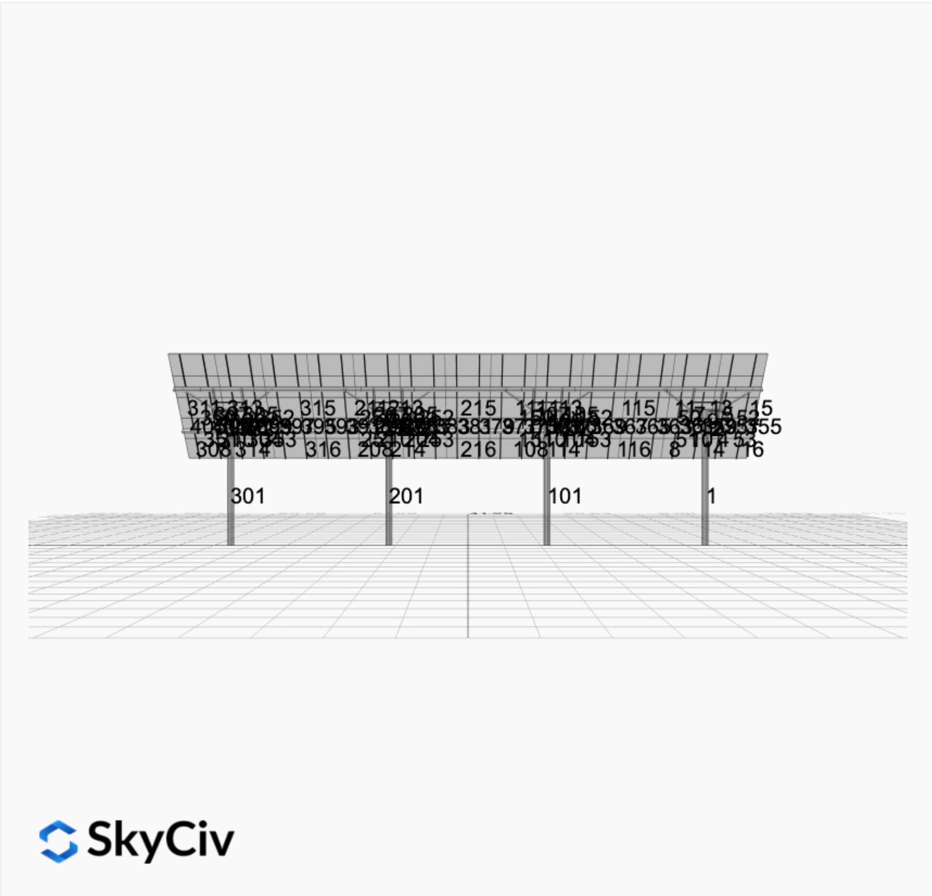
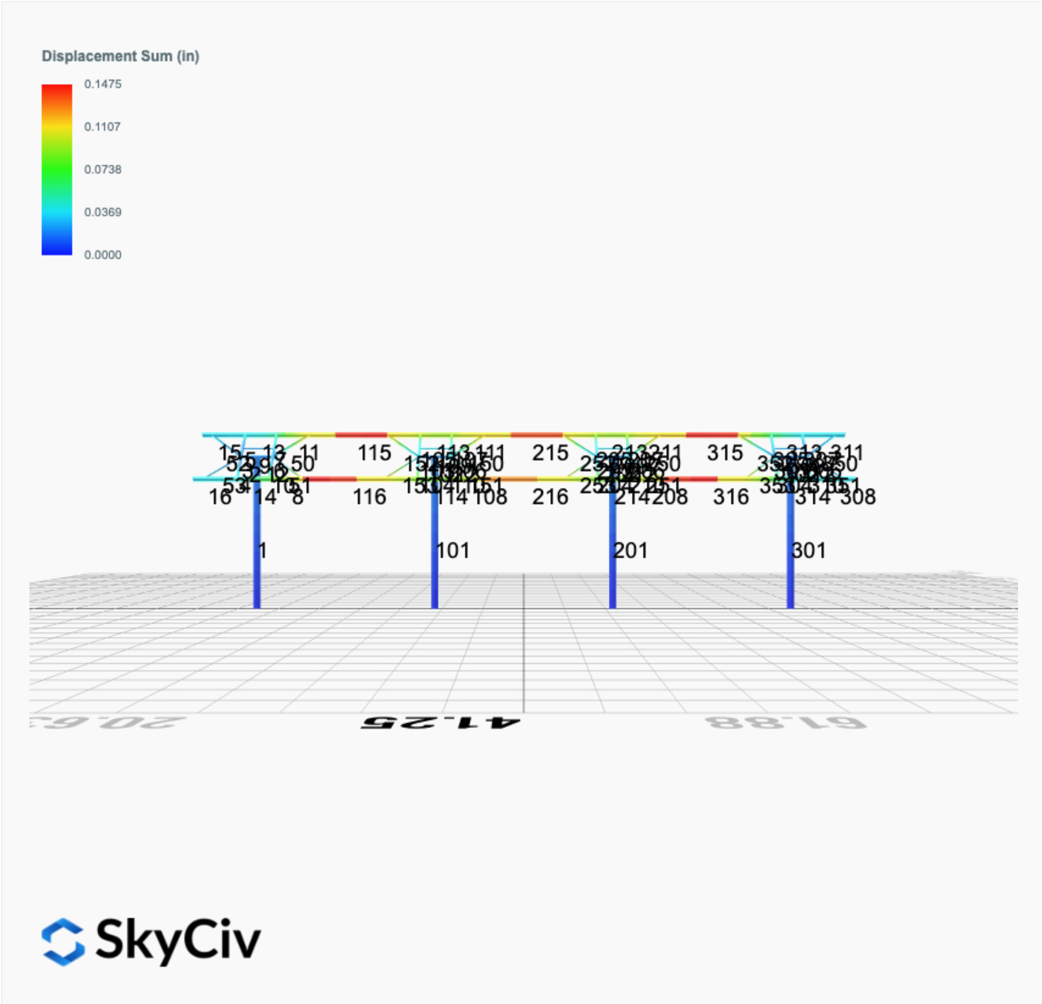
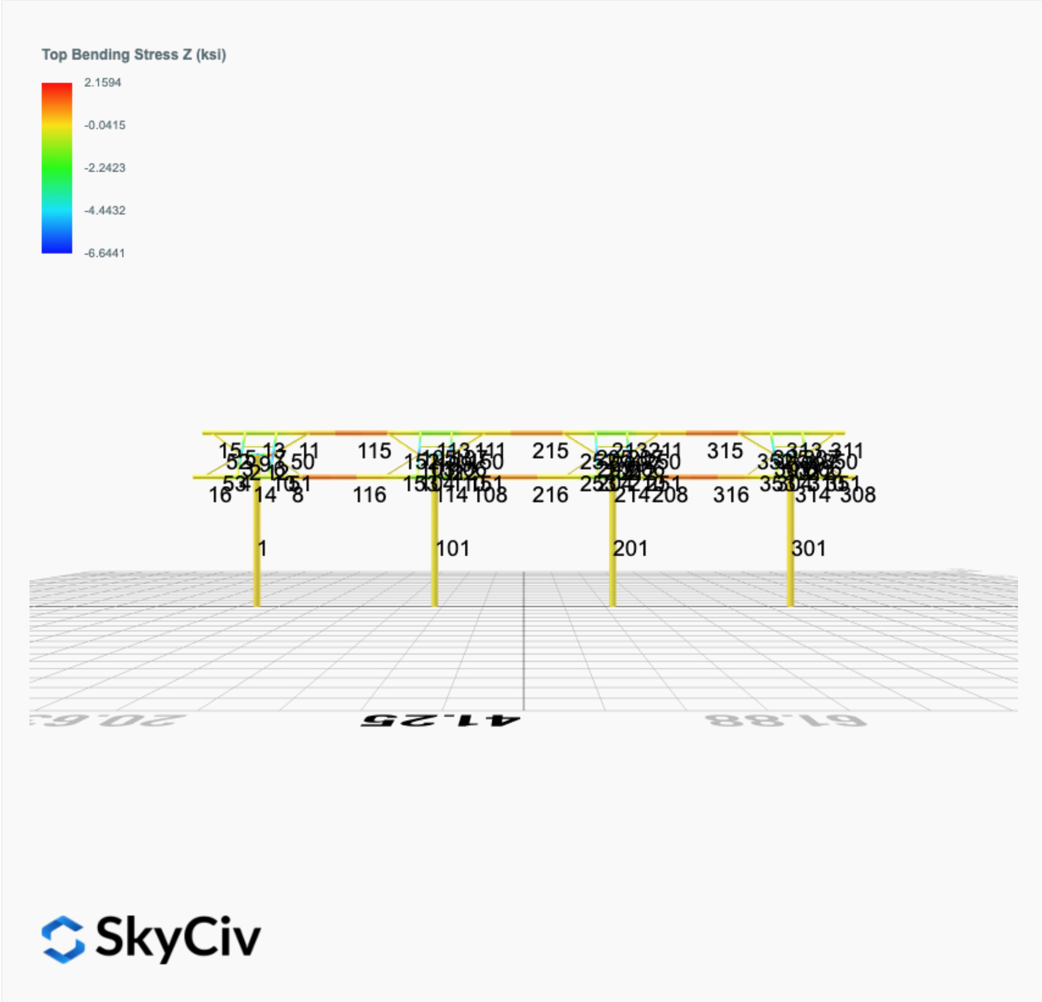
SkyCiv




301
201
101
1

# FEM Results (Envelope Worst Case for each member)

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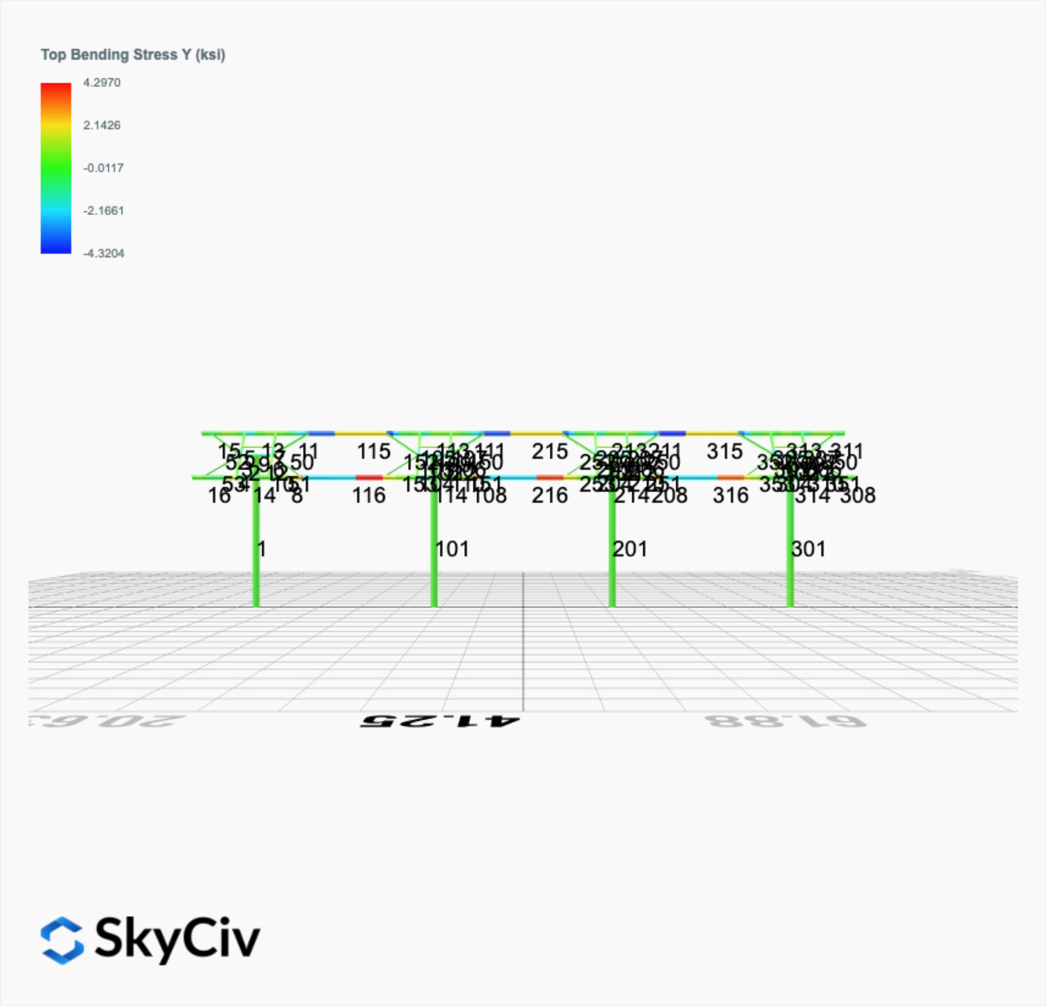
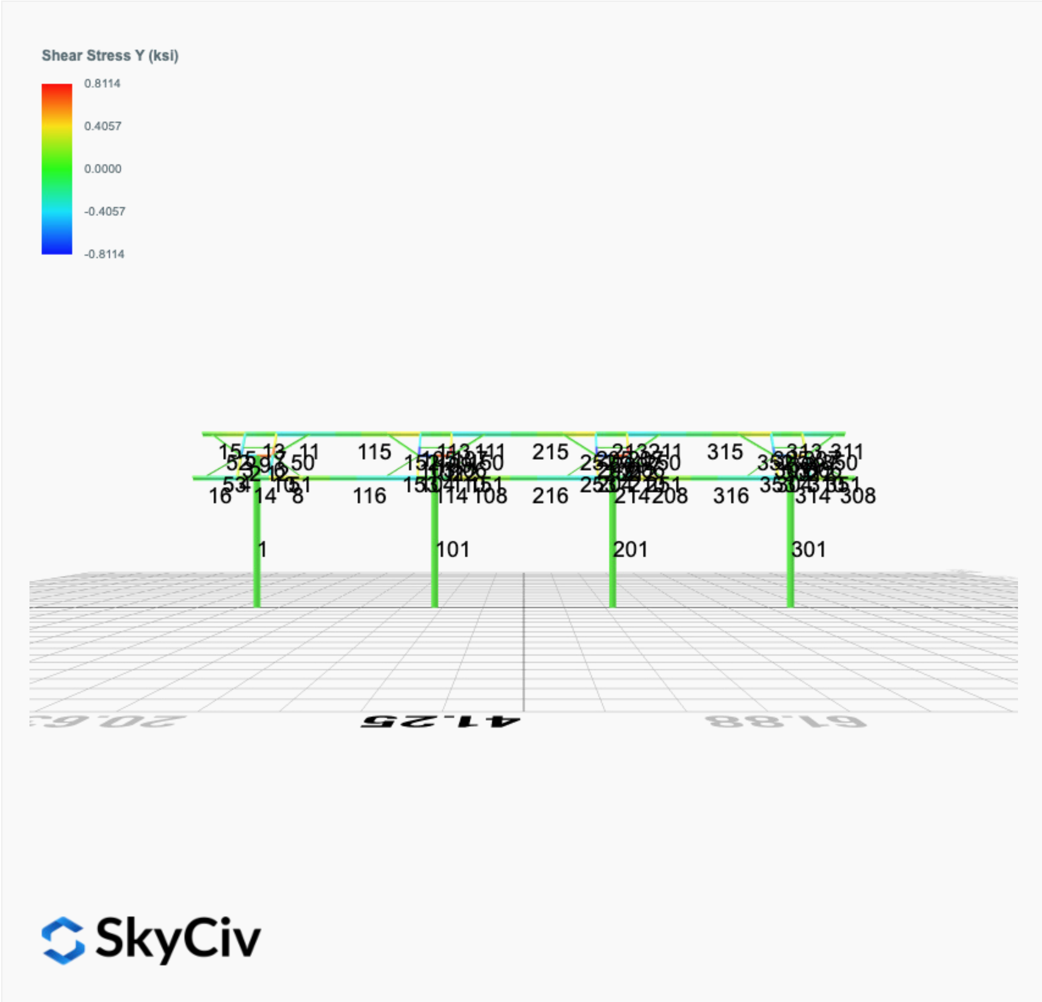
-0.0415
-2.2423
-4.4432
-6.6441
1
101
201
301


Top Bending Stress Y (ksi)
4.2970
2.1426
-0.0117
-2.1661
-4.3204
115
215
315
116
216
316
1
101
201
301
41.25
61.88
SkyCiv


Shear Stress Y (ksi)
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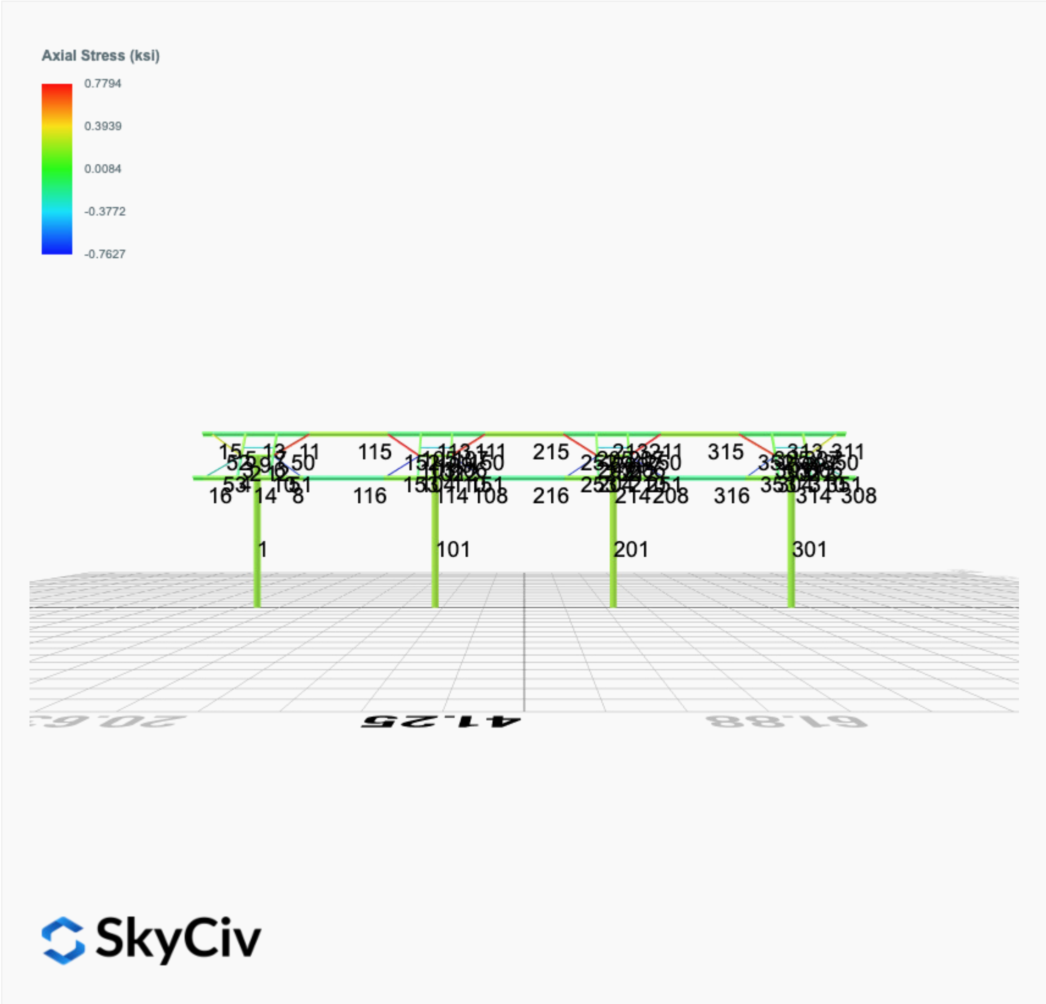
0.4057
0.0000
-0.4057
-0.8114
115
215
315
116
216
316
1
101
201
301


Axial Stress (ksi)
0.7794
0.3939
0.0084
-0.3772
-0.7627
SkyCiv

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

### ASD Load Combination Results

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 1. D | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 2. D + L | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 3. D + (S or Lr or R) | 0.0408 | 5.9694 | 0.0946 | 0.5527 | -0.3911 | -0.7361 |
| ULS: 3. D + (S or Lr or R) | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0350 | 5.3419 | 0.0812 | 0.4743 | -0.3352 | -0.6293 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 5b. D + 0.7E | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0350 | 5.3419 | 0.0812 | 0.4743 | -0.3352 | -0.6293 |
| ULS: 8. 0.6D + 0.7E | 0.0106 | 2.0755 | 0.0245 | 0.1434 | -0.1005 | -0.1852 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.1941 | 6.8284 | 0.2110 | 1.2092 | -1.9549 | 81.8585 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.2158 | 0.0937 | -0.1256 | -0.7109 | 1.5798 | -79.9455 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1237 | 7.8687 | 0.2088 | 1.2020 | -1.6757 | 60.9962 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0350 | 5.3419 | 0.0812 | 0.4743 | -0.3352 | -0.6293 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1836 | 2.8177 | -0.0437 | -0.2381 | 0.9753 | -60.3568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0350 | 5.3419 | 0.0812 | 0.4743 | -0.3352 | -0.6293 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1411 | 5.9861 | 0.1685 | 0.9666 | -1.5081 | 61.3167 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1662 | 0.9351 | -0.0840 | -0.4734 | 1.1429 | -60.0363 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0176 | 3.4592 | 0.0409 | 0.2389 | -0.1675 | -0.3087 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.2011 | 5.4447 | 0.1947 | 1.1136 | -1.8879 | 81.9820 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0106 | 2.0755 | 0.0245 | 0.1434 | -0.1005 | -0.1852 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.2087 | -1.2900 | -0.1420 | -0.8065 | 1.6468 | -79.8220 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0106 | 2.0755 | 0.0245 | 0.1434 | -0.1005 | -0.1852 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 11.0193 |
| Shear X | -7.0348 |
| Shear Z | 0.3638 |
| Moment X | 2.0892 |
| Moment Y (Twist) | 3.3335 |
| Moment Z | 138.5002 |

### 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 | 7.8687 |
| Shear X | -4.2158 |
| Shear Z | 0.2110 |
| Moment X | 1.2092 |
| Moment Y (Twist) | 1.9549 |
| Moment Z | 81.9820 |

## 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 | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 2. D + L | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 3. D + (S or Lr or R) | -0.0408 | 6.9759 | -0.0052 | -0.0298 | 0.0477 | 0.8126 |
| ULS: 3. D + (S or Lr or R) | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0350 | 6.2062 | -0.0045 | -0.0256 | 0.0409 | 0.6988 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 5b. D + 0.7E | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0350 | 6.2062 | -0.0045 | -0.0256 | 0.0409 | 0.6988 |
| ULS: 8. 0.6D + 0.7E | -0.0106 | 2.3384 | -0.0013 | -0.0077 | 0.0123 | 0.2144 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.9566 | 8.2065 | 0.0179 | 0.1046 | -0.2702 | 96.7374 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.9349 | -0.4154 | -0.0205 | -0.1219 | 0.2865 | -92.9072 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.7392 | 9.4381 | 0.0106 | 0.0626 | -0.1771 | 72.9839 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0350 | 6.2062 | -0.0045 | -0.0256 | 0.0409 | 0.6988 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6793 | 2.9717 | -0.0182 | -0.1074 | 0.2404 | -69.2495 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0350 | 6.2062 | -0.0045 | -0.0256 | 0.0409 | 0.6988 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.7218 | 7.1292 | 0.0128 | 0.0753 | -0.1975 | 72.6423 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6967 | 0.6628 | -0.0160 | -0.0947 | 0.2200 | -69.5911 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0176 | 3.8974 | -0.0022 | -0.0129 | 0.0205 | 0.3573 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.9495 | 6.6476 | 0.0188 | 0.1098 | -0.2784 | 96.5944 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0106 | 2.3384 | -0.0013 | -0.0077 | 0.0123 | 0.2144 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.9419 | -1.9743 | -0.0196 | -0.1168 | 0.2783 | -93.0501 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0106 | 2.3384 | -0.0013 | -0.0077 | 0.0123 | 0.2144 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 13.4000 |
| Shear X | -8.2578 |
| Shear Z | -0.0363 |
| Moment X | -0.2166 |
| Moment Y (Twist) | 0.4984 |
| Moment Z | 163.9358 |

### 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 | 9.4381 |
| Shear X | -4.9566 |
| Shear Z | -0.0205 |
| Moment X | -0.1219 |
| Moment Y (Twist) | 0.2865 |
| Moment Z | 96.7374 |

## 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 | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 2. D + L | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 3. D + (S or Lr or R) | -0.0408 | 6.9759 | 0.0052 | 0.0298 | -0.0477 | 0.8126 |
| ULS: 3. D + (S or Lr or R) | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0350 | 6.2062 | 0.0045 | 0.0256 | -0.0409 | 0.6988 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 5b. D + 0.7E | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0350 | 6.2062 | 0.0045 | 0.0256 | -0.0409 | 0.6988 |
| ULS: 8. 0.6D + 0.7E | -0.0106 | 2.3384 | 0.0013 | 0.0077 | -0.0123 | 0.2144 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.9566 | 8.2065 | -0.0179 | -0.1046 | 0.2702 | 96.7374 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.9349 | -0.4154 | 0.0205 | 0.1220 | -0.2865 | -92.9072 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |

| 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 | -3.7392 | 9.4381 | -0.0106 | -0.0625 | 0.1771 | 72.9839 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0350 | 6.2062 | 0.0045 | 0.0256 | -0.0409 | 0.6988 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6793 | 2.9717 | 0.0182 | 0.1074 | -0.2404 | -69.2495 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0350 | 6.2062 | 0.0045 | 0.0256 | -0.0409 | 0.6988 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.7218 | 7.1292 | -0.0128 | -0.0752 | 0.1975 | 72.6423 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.6967 | 0.6628 | 0.0160 | 0.0947 | -0.2200 | -69.5911 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0176 | 3.8974 | 0.0022 | 0.0129 | -0.0205 | 0.3573 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.9495 | 6.6475 | -0.0188 | -0.1098 | 0.2784 | 96.5944 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0106 | 2.3384 | 0.0013 | 0.0077 | -0.0123 | 0.2144 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.9419 | -1.9743 | 0.0196 | 0.1168 | -0.2783 | -93.0501 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0106 | 2.3384 | 0.0013 | 0.0077 | -0.0123 | 0.2144 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 13.4000 |
| Shear X | -8.2579 |
| Shear Z | 0.0363 |
| Moment X | 0.2176 |
| Moment Y (Twist) | 0.4990 |
| Moment Z | 163.9359 |

### 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 | 9.4381 |
| Shear X | -4.9566 |
| Shear Z | 0.0205 |
| Moment X | 0.1220 |
| Moment Y (Twist) | 0.2865 |
| Moment Z | 96.7374 |

## 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 | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 2. D + L | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 3. D + (S or Lr or R) | 0.0408 | 5.9694 | -0.0946 | -0.5527 | 0.3911 | -0.7361 |
| ULS: 3. D + (S or Lr or R) | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0350 | 5.3419 | -0.0812 | -0.4743 | 0.3352 | -0.6292 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 5b. D + 0.7E | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0350 | 5.3419 | -0.0812 | -0.4743 | 0.3352 | -0.6292 |
| ULS: 8. 0.6D + 0.7E | 0.0106 | 2.0755 | -0.0245 | -0.1434 | 0.1005 | -0.1852 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.1941 | 6.8284 | -0.2110 | -1.2092 | 1.9549 | 81.8586 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.2158 | 0.0937 | 0.1256 | 0.7109 | -1.5798 | -79.9454 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1237 | 7.8687 | -0.2088 | -1.2020 | 1.6757 | 60.9962 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0350 | 5.3419 | -0.0812 | -0.4743 | 0.3352 | -0.6292 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1836 | 2.8177 | 0.0437 | 0.2381 | -0.9753 | -60.3568 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0350 | 5.3419 | -0.0812 | -0.4743 | 0.3352 | -0.6292 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1411 | 5.9861 | -0.1685 | -0.9666 | 1.5081 | 61.3168 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1662 | 0.9351 | 0.0840 | 0.4734 | -1.1429 | -60.0362 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0176 | 3.4592 | -0.0409 | -0.2389 | 0.1676 | -0.3087 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.2011 | 5.4447 | -0.1947 | -1.1136 | 1.8879 | 81.9820 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0106 | 2.0755 | -0.0245 | -0.1434 | 0.1005 | -0.1852 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.2087 | -1.2900 | 0.1420 | 0.8065 | -1.6468 | -79.8220 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0106 | 2.0755 | -0.0245 | -0.1434 | 0.1005 | -0.1852 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 11.0195 |
| Shear X | -7.0348 |
| Shear Z | -0.3638 |
| Moment X | -2.0899 |
| Moment Y (Twist) | 3.3343 |
| Moment Z | 138.5009 |

### 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 | 7.8687 |
| Shear X | -4.2158 |
| Shear Z | -0.2110 |
| Moment X | -1.2092 |
| Moment Y (Twist) | 1.9549 |
| Moment Z | 81.9820 |

## Project Details

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

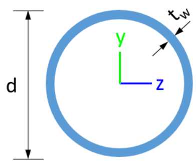
User Name: sales@mtsolar.us
Unit System: imperial

## Design Input Information

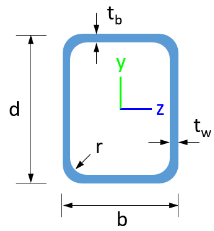
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

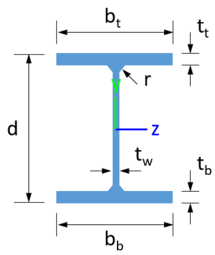
**Section Dimensions**



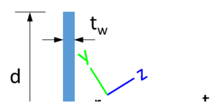

| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | | |
| 12 | 10in Pipe Sch 80 | 10.75 | 0.59 | | | | | |

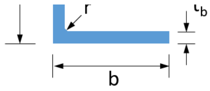



| ID | Name | d (in) | b (in) | $t_w$ (in) | $t_b$ (in) | r (in) | | |
|---|---|---|---|---|---|---|---|---|
| 16 | HSS5x3x3/16 | 5.00 | 3.00 | 0.17 | 0.17 | 0.17 | | |




| 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 |






| ID | Name | d (in) | $t_w$ (in) | b (in) | $t_b$ (in) | r (in) | | |
|---|---|---|---|---|---|---|---|---|
| 34 | L3x2x3/16 | 3.00 | 0.19 | 2.00 | 0.19 | 0.31 | | |

| Section Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | Name | A ($in^2$) | J ($in^4$) | $I_{yp}$ ($in^4$) | $I_{zp}$ ($in^4$) | $I_w$ ($in^6$) | $S_{yp}$ ($in^3$) | $S_{zp}$ ($in^3$) |
| 2 | 2in Pipe Sch 80 | 1.48 | 1.74 | 0.87 | 0.87 | 0.00 | 1.02 | 1.02 |
| 5 | 4in Pipe Sch 80 | 4.41 | 19.22 | 9.61 | 9.61 | 0.00 | 5.85 | 5.85 |
| 12 | 10in Pipe Sch 80 | 18.92 | 489.69 | 244.84 | 244.84 | 0.00 | 61.25 | 61.25 |
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 0.73 | 2.96 | 4.21 |
| 19 | W8x10 | 2.96 | 0.04 | 2.09 | 30.80 | 30.90 | 1.66 | 8.87 |
| 34 | L3x2x3/16 | 0.92 | 0.01 | 0.17 | 0.98 | 0.01 | 0.33 | 0.82 |

| Member Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 12 | 40.32 | 40.32 | 19.20 | - | 300 | 200 | 1 |
| 2 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.02,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.53,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.57,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 1.77,1.76,1.77,1.75,1.76,1.77,1.83,1.76,1.87,1.76,1.83,1.77,1.85,1.77,1.80,1.75,2.32,1.75,1.82,1.77,1.88,1.77,1.83,1.77,1.85,1.77 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 1.84,1.82,1.84,1.82,1.83,1.84,2.08,1.82,2.10,1.82,2.08,1.84,2.09,1.84,2.00,1.82,1.60,1.82,2.08,1.84,2.10,1.84,2.08,1.84,2.09,1.84 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.05,1.07,1.08,1.07,1.05,1.07,1.07,1.07,1.05,1.07,1.42,1.07,1.04,1.07,1.09,1.07,1.05,1.07,1.07,1.07 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.05,1.07,1.04,1.07,1.05,1.07,1.04,1.07,1.05,1.07,1.25,1.07,1.05,1.07,1.05,1.07,1.05,1.07,1.04,1.07 | 300 | 200 | 1 |
| 15 | 19 | 3.75 | 3.75 | 3.75 | 2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32 | 300 | 200 | 1 |
| 16 | 19 | 3.75 | 3.75 | 3.75 | 2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32 | 300 | 200 | 1 |
| 50 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 51 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 52 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 53 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 101 | 12 | 40.32 | 40.32 | 19.20 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.09,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.60,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.60,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67 | 300 | 200 | 1 |
| 108 | 19 | 1.33 | 1.33 | 2.05 | 2.25,2.25,2.25,2.24,2.25,2.25,2.29,2.25,2.32,2.25,2.29,2.25,2.31,2.25,2.27,2.24,1.45,2.24,2.28,2.25,2.33,2.25,2.29,2.25,2.31,2.25 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 111 | 19 | 1.33 | 1.33 | 2.05 | 2.26,2.26,2.26,2.26,2.26,2.26,2.28,2.26,2.12,2.26,2.23,2.26,2.13,2.26,2.33,2.26,1.20,2.26,2.36,2.26,2.11,2.26,2.20,2.26,2.14,2.26 | 300 | 200 | 1 |
| 112 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.06,1.03,1.04,1.03,2.07,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.05,1.03,1.05,1.03,1.04,1.03,1.48,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03 | 300 | 200 | 1 |
| 115 | 19 | 12.95 | 12.95 | 12.95 | 1.17,1.17,1.17,1.17,1.17,1.17,1.13,1.17,1.12,1.17,1.13,1.17,1.13,1.17,1.15,1.17,1.18,1.17,1.14,1.17,1.13,1.17,1.13,1.17,1.13,1.17 | 300 | 200 | 1 |
| 116 | 19 | 12.95 | 12.95 | 12.95 | 1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.15,1.18,1.16,1.18,1.16,1.18,1.17,1.18,1.11,1.18,1.16,1.18,1.15,1.18,1.16,1.18,1.16,1.18 | 300 | 200 | 1 |
| 150 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 151 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 152 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 153 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 201 | 12 | 40.32 | 40.32 | 19.20 | - | 300 | 200 | 1 |
| 202 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 204 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 205 | 16 | 1.52 | 1.52 | 2.33 | 1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67 | 300 | 200 | 1 |
| 206 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.09,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 207 | 16 | 1.52 | 1.52 | 2.33 | 1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.60,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67 | 300 | 200 | 1 |
| 208 | 19 | 1.33 | 1.33 | 2.05 | 2.31,2.31,2.31,2.31,2.31,2.31,2.17,2.31,2.13,2.31,2.15,2.31,2.14,2.31,2.34,2.31,1.25,2.31,2.21,2.31,2.12,2.31,2.15,2.31,2.14,2.31 | 300 | 200 | 1 |
| 209 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.60,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 211 | 19 | 1.33 | 1.33 | 2.05 | 2.33,2.33,2.33,2.34,2.33,2.33,2.10,2.33,1.97,2.33,2.09,2.33,2.07,2.33,2.12,2.34,1.06,2.34,2.10,2.33,1.86,2.33,2.09,2.33,2.08,2.33 | 300 | 200 | 1 |
| 212 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.06,1.03,1.04,1.03,2.07,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03 | 300 | 200 | 1 |
| 214 | 19 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.05,1.03,1.05,1.03,1.04,1.03,1.47,1.03,1.04,1.03,1.06,1.03,1.05,1.03,1.05,1.03 | 300 | 200 | 1 |
| 215 | 19 | 12.95 | 12.95 | 12.95 | 1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.14,1.16,1.14,1.16,1.14,1.16,1.15,1.16,1.05,1.16,1.15,1.16,1.13,1.16,1.14,1.16,1.14,1.16 | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 216 | 19 | 12.95 | 12.95 | 12.95 | [illegible]5,1.17,1.16,1.17,1.16,1.17 | 300 | 200 | 1 |
| 250 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 251 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 252 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 253 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 301 | 12 | 40.32 | 40.32 | 19.20 | - | 300 | 200 | 1 |
| 302 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 303 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 304 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 305 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 306 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.02,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18 | 300 | 200 | 1 |
| 307 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.57,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 308 | 19 | 3.75 | 3.75 | 3.75 | 2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32 | 300 | 200 | 1 |
| 309 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 310 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.53,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 311 | 19 | 3.75 | 3.75 | 3.75 | 2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32,2.32 | 300 | 200 | 1 |
| 312 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 313 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.05,1.07,1.08,1.07,1.05,1.07,1.07,1.07,1.05,1.07,1.42,1.07,1.04,1.07,1.09,1.07,1.05,1.07,1.07,1.07 | 300 | 200 | 1 |
| 314 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.05,1.07,1.04,1.07,1.05,1.07,1.04,1.07,1.05,1.07,1.25,1.07,1.05,1.07,1.05,1.07,1.05,1.07,1.04,1.07 | 300 | 200 | 1 |
| 315 | 19 | 12.95 | 12.95 | 12.95 | 1.14,1.14,1.14,1.14,1.14,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.44,1.14,1.13,1.14,1.14,1.14,1.13,1.14,1.13,1.14 | 300 | 200 | 1 |
| 316 | 19 | 12.95 | 12.95 | 12.95 | 1.14,1.14,1.14,1.14,1.14,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.21,1.14,1.13,1.14,1.13,1.14,1.13,1.14,1.13,1.14 | 300 | 200 | 1 |
| 350 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 351 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 352 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |
| 353 | 34 | 5.67 | 5.67 | 5.67 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14 | 300 | 200 | 250 |

## Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|---|---|---|---|---|---|---|
| 1 | 851.50 | 236.34 | 229.67 | 229.67 | 255.45 | 255.45 |
| 2 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 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 | 23.93 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 85.85 | 23.79 | 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 | 0.76 | 15.23 | 10.15 |
| 51 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 52 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 53 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 101 | 851.50 | 236.34 | 229.67 | 229.67 | 255.45 | 255.45 |
| 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 | 23.67 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 85.85 | 23.64 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 19.55 | 12.18 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 19.55 | 12.06 | 6.12 | 40.24 | 43.62 |
| 150 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 151 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 152 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 153 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 201 | 851.50 | 236.34 | 229.67 | 229.67 | 255.45 | 255.45 |
| 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 | 23.67 | 6.12 | 40.24 | 43.62 |
| 214 | 133.20 | 85.85 | 23.64 | 6.12 | 40.24 | 43.62 |
| 215 | 133.20 | 19.55 | 11.43 | 6.12 | 40.24 | 43.62 |
| 216 | 133.20 | 19.55 | 11.74 | 6.12 | 40.24 | 43.62 |
| 250 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 251 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 252 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 253 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 301 | 851.50 | 236.34 | 229.67 | 229.67 | 255.45 | 255.45 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 301 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 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 | 23.93 | 6.12 | 40.24 | 43.62 |
| 314 | 133.20 | 85.85 | 23.80 | 6.12 | 40.24 | 43.62 |
| 315 | 133.20 | 19.55 | 12.19 | 6.12 | 40.24 | 43.62 |
| 316 | 133.20 | 19.55 | 12.24 | 6.12 | 40.24 | 43.62 |
| 350 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 351 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 352 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |
| 353 | 41.27 | 8.45 | 1.63 | 0.76 | 15.23 | 10.15 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.047 | 0.603 | 0.021 | 0.028 | 0.001 | 0.635 | #13 | 0.672 | Not Required | Pass |
| 2 | 0.005 | 0.255 | 0.228 | 0.066 | 0.049 | 0.478 | #13 | 0.053 | Not Required | Pass |
| 3 | 0.007 | 0.554 | 0.110 | 0.054 | 0.046 | 0.608 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.006 | 0.554 | 0.058 | 0.056 | 0.010 | 0.609 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.006 | 0.344 | 0.032 | 0.055 | 0.009 | 0.358 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.004 | 0.816 | 0.132 | 0.084 | 0.051 | 0.888 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.003 | 0.506 | 0.012 | 0.081 | 0.005 | 0.512 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.005 | 0.097 | 0.144 | 0.054 | 0.012 | 0.191 | #15 | 0.095 | Not Required | Pass |
| 9 | 0.019 | 0.081 | 0.092 | 0.004 | 0.003 | 0.177 | #13 | 0.136 | Not Required | Pass |
| 10 | 0.005 | 0.789 | 0.061 | 0.079 | 0.008 | 0.794 | #13 | 0.120 | Not Required | Pass |
| 11 | 0.003 | 0.086 | 0.143 | 0.057 | 0.012 | 0.177 | #15 | 0.063 | Not Required | Pass |
| 12 | 0.005 | 0.473 | 0.380 | 0.096 | 0.070 | 0.854 | #13 | 0.053 | Not Required | Pass |
| 13 | 0.004 | 0.236 | 0.064 | 0.070 | 0.009 | 0.266 | #13 | 0.190 | Not Required | Pass |
| 14 | 0.008 | 0.226 | 0.064 | 0.068 | 0.009 | 0.281 | #13 | 0.286 | Not Required | Pass |
| 15 | 0.004 | 0.066 | 0.022 | 0.029 | 0.006 | 0.079 | #13 | 0.179 | Not Required | Pass |
| 16 | 0.004 | 0.066 | 0.017 | 0.029 | 0.005 | 0.076 | #13 | 0.179 | Not Required | Pass |
| 50 | 0.231 | 0.009 | 0.006 | 0.003 | 0.002 | 0.244 | #23 | 0.783 | Not Required | Pass |
| 51 | 0.047 | 0.004 | 0.016 | 0.001 | 0.001 | 0.062 | #23 | 0.522 | Not Required | Pass |
| 52 | 0.076 | 0.009 | 0.006 | 0.001 | 0.001 | 0.088 | #21 | 0.783 | Not Required | Pass |
| 53 | 0.015 | 0.004 | 0.017 | 0.001 | 0.001 | 0.033 | #21 | 0.522 | Not Required | Pass |
| 101 | 0.057 | 0.714 | 0.002 | 0.032 | 0.000 | 0.743 | #13 | 0.672 | Not Required | Pass |
| 102 | 0.007 | 0.442 | 0.353 | 0.099 | 0.068 | 0.797 | #13 | 0.053 | Not Required | Pass |
| 103 | 0.004 | 0.810 | 0.149 | 0.081 | 0.060 | 0.903 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.004 | 0.822 | 0.051 | 0.083 | 0.006 | 0.853 | #13 | 0.120 | Not Required | Pass |
| 105 | 0.004 | 0.503 | 0.028 | 0.081 | 0.011 | 0.520 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.003 | 0.845 | 0.147 | 0.085 | 0.060 | 0.936 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.003 | 0.525 | 0.032 | 0.084 | 0.012 | 0.549 | #13 | 0.074 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 108 | 0.010 | 0.079 | 0.114 | 0.057 | 0.010 | 0.151 | #21 | 0.095 | Not Required | Pass |
| 109 | 0.025 | 0.064 | 0.073 | 0.001 | 0.000 | 0.145 | #13 | 0.136 | Not Required | Pass |
| 110 | 0.003 | 0.840 | 0.054 | 0.084 | 0.007 | 0.866 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.007 | 0.065 | 0.114 | 0.058 | 0.010 | 0.157 | #21 | 0.095 | Not Required | Pass |
| 112 | 0.007 | 0.461 | 0.374 | 0.101 | 0.071 | 0.837 | #13 | 0.053 | Not Required | Pass |
| 113 | 0.007 | 0.293 | 0.044 | 0.071 | 0.007 | 0.321 | #13 | 0.286 | Not Required | Pass |
| 114 | 0.015 | 0.323 | 0.035 | 0.073 | 0.007 | 0.348 | #13 | 0.286 | Not Required | Pass |
| 115 | 0.056 | 0.561 | 0.201 | 0.058 | 0.016 | 0.645 | #13 | 0.925 | Not Required | Pass |
| 116 | 0.064 | 0.549 | 0.203 | 0.060 | 0.017 | 0.638 | #13 | 0.925 | Not Required | Pass |
| 150 | 0.212 | 0.009 | 0.006 | 0.002 | 0.002 | 0.225 | #23 | 0.783 | Not Required | Pass |
| 151 | 0.042 | 0.004 | 0.016 | 0.001 | 0.001 | 0.058 | #23 | 0.522 | Not Required | Pass |
| 152 | 0.241 | 0.009 | 0.006 | 0.003 | 0.002 | 0.253 | #21 | 0.783 | Not Required | Pass |
| 153 | 0.049 | 0.004 | 0.016 | 0.001 | 0.001 | 0.064 | #21 | 0.522 | Not Required | Pass |
| 201 | 0.057 | 0.714 | 0.002 | 0.032 | 0.000 | 0.743 | #13 | 0.672 | Not Required | Pass |
| 202 | 0.007 | 0.461 | 0.374 | 0.101 | 0.071 | 0.837 | #13 | 0.053 | Not Required | Pass |
| 203 | 0.003 | 0.845 | 0.147 | 0.085 | 0.060 | 0.936 | #13 | 0.045 | Not Required | Pass |
| 204 | 0.003 | 0.840 | 0.054 | 0.084 | 0.007 | 0.866 | #13 | 0.080 | Not Required | Pass |
| 205 | 0.003 | 0.525 | 0.032 | 0.084 | 0.012 | 0.549 | #13 | 0.074 | Not Required | Pass |
| 206 | 0.004 | 0.810 | 0.149 | 0.081 | 0.060 | 0.903 | #13 | 0.045 | Not Required | Pass |
| 207 | 0.004 | 0.503 | 0.028 | 0.081 | 0.011 | 0.520 | #13 | 0.074 | Not Required | Pass |
| 208 | 0.010 | 0.065 | 0.162 | 0.060 | 0.012 | 0.218 | #13 | 0.095 | Not Required | Pass |
| 209 | 0.025 | 0.064 | 0.073 | 0.001 | 0.000 | 0.145 | #13 | 0.136 | Not Required | Pass |
| 210 | 0.004 | 0.822 | 0.051 | 0.083 | 0.006 | 0.853 | #13 | 0.120 | Not Required | Pass |
| 211 | 0.007 | 0.081 | 0.158 | 0.058 | 0.013 | 0.225 | #13 | 0.095 | Not Required | Pass |
| 212 | 0.007 | 0.442 | 0.353 | 0.099 | 0.068 | 0.797 | #13 | 0.053 | Not Required | Pass |
| 213 | 0.007 | 0.293 | 0.044 | 0.071 | 0.007 | 0.321 | #13 | 0.286 | Not Required | Pass |
| 214 | 0.015 | 0.323 | 0.035 | 0.073 | 0.007 | 0.348 | #13 | 0.286 | Not Required | Pass |
| 215 | 0.062 | 0.488 | 0.150 | 0.058 | 0.015 | 0.538 | #13 | 0.925 | Not Required | Pass |
| 216 | 0.064 | 0.446 | 0.147 | 0.057 | 0.015 | 0.511 | #13 | 0.925 | Not Required | Pass |
| 250 | 0.241 | 0.009 | 0.006 | 0.003 | 0.002 | 0.253 | #21 | 0.783 | Not Required | Pass |
| 251 | 0.049 | 0.004 | 0.016 | 0.001 | 0.001 | 0.064 | #21 | 0.522 | Not Required | Pass |
| 252 | 0.212 | 0.009 | 0.006 | 0.002 | 0.002 | 0.225 | #23 | 0.783 | Not Required | Pass |
| 253 | 0.042 | 0.004 | 0.016 | 0.001 | 0.001 | 0.058 | #23 | 0.522 | Not Required | Pass |
| 301 | 0.047 | 0.603 | 0.021 | 0.028 | 0.001 | 0.635 | #13 | 0.672 | Not Required | Pass |
| 302 | 0.005 | 0.473 | 0.380 | 0.096 | 0.070 | 0.854 | #13 | 0.053 | Not Required | Pass |
| 303 | 0.004 | 0.816 | 0.132 | 0.084 | 0.051 | 0.888 | #13 | 0.045 | Not Required | Pass |
| 304 | 0.005 | 0.789 | 0.061 | 0.079 | 0.008 | 0.794 | #13 | 0.120 | Not Required | Pass |
| 305 | 0.003 | 0.506 | 0.012 | 0.081 | 0.005 | 0.512 | #13 | 0.074 | Not Required | Pass |
| 306 | 0.007 | 0.554 | 0.110 | 0.054 | 0.046 | 0.608 | #13 | 0.045 | Not Required | Pass |
| 307 | 0.006 | 0.344 | 0.032 | 0.055 | 0.009 | 0.359 | #13 | 0.074 | Not Required | Pass |
| 308 | 0.004 | 0.066 | 0.017 | 0.029 | 0.005 | 0.076 | #13 | 0.268 | Not Required | Pass |
| 309 | 0.019 | 0.081 | 0.092 | 0.004 | 0.003 | 0.177 | #13 | 0.136 | Not Required | Pass |
| 310 | 0.006 | 0.554 | 0.058 | 0.056 | 0.010 | 0.609 | #13 | 0.080 | Not Required | Pass |
| 311 | 0.004 | 0.066 | 0.022 | 0.029 | 0.006 | 0.079 | #13 | 0.179 | Not Required | Pass |
| 312 | 0.005 | 0.255 | 0.228 | 0.066 | 0.049 | 0.478 | #13 | 0.053 | Not Required | Pass |
| 313 | 0.004 | 0.236 | 0.064 | 0.070 | 0.009 | 0.266 | #13 | 0.190 | Not Required | Pass |
| 314 | 0.008 | 0.226 | 0.064 | 0.068 | 0.009 | 0.281 | #13 | 0.286 | Not Required | Pass |
| 315 | 0.056 | 0.564 | 0.201 | 0.057 | 0.016 | 0.647 | #13 | 0.616 | Not Required | Pass |
| 316 | 0.064 | 0.563 | 0.203 | 0.054 | 0.017 | 0.652 | #13 | 0.925 | Not Required | Pass |
| 350 | 0.076 | 0.009 | 0.006 | 0.001 | 0.001 | 0.088 | #21 | 0.783 | Not Required | Pass |
| 351 | 0.015 | 0.004 | 0.017 | 0.001 | 0.001 | 0.033 | #21 | 0.522 | Not Required | Pass |
| 352 | 0.231 | 0.009 | 0.006 | 0.003 | 0.002 | 0.244 | #23 | 0.783 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 353 | 0.047 | 0.004 | 0.017 | 0.001 | 0.001 | 0.062 | #23 | 0.522 | Not Required | Pass |

## Definitions

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

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

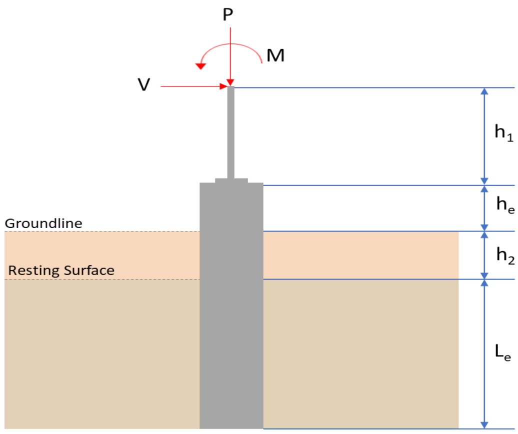
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 9.5 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure $(q_a)$ (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) | 7.869 | 11.019 |
| $V_x$ (kip) | -4.216 | -7.035 |
| $V_z$ (kip) | 0.211 | 0.364 |
| $M_x$ (kipft) | 1.209 | 2.089 |
| $M_z$ (kipft) | 81.982 | 138.500 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.216 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.67134 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(81.982\ \text{kipft}) + ((-4.216\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 13.054\ \text{kipft/ft}$$

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:
$L_{e,x} = 8.8308\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.211\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.033599\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.209\ \text{kipft}) + ((0.211\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.19252\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.7572\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.8308\ \text{ft}), (2.7572\ \text{ft})]$$

$$L_{e,req} = 8.831\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.831\ \text{ft})}{(9.5\ \text{ft})}$$

$$Ratio = 0.92958$$

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

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

$$q = \frac{(7.869\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.49181\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.49181\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.24591$$

Status: **PASS**
Ratio: **0.250**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.67134\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 13.054\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.054\ \text{kipft/ft}) \times (9.5\ \text{ft})) + \left(3 \times (-0.67134\ \text{kip/ft}) \times (9.5\ \text{ft})^2\right)}{(6 \times (13.054\ \text{kipft/ft})) + (4 \times (-0.67134\ \text{kip/ft}) \times (9.5\ \text{ft}))}$$

$$a = 6.5278\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (13.054\ \text{kipft/ft})) + (3 \times (-0.67134\ \text{kip/ft}) \times (9.5\ \text{ft}))]^{\ 2}}{(9.5\ \text{ft})^2 \times [(3 \times (13.054\ \text{kipft/ft})) + (2 \times (-0.67134\ \text{kip/ft}) \times (9.5\ \text{ft}))]}$$

$$p = 0.34446\ \text{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (13.054\ \text{kipft/ft})) + ((-0.67134\ \text{kip/ft}) \times (9.5\ \text{ft}))]}{(9.5\ \text{ft})^2}$$

$$s = 1.3118\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.5278\ \text{ft})}{2}$$

$$p_a = 0.48959\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

| | | |
|---|---|---|
| | $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.34446\ \mathrm{kip/ft^2}\right)}{\left(0.48959\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.70356$$ | Status: **PASS**<br>Ratio: **0.700** |
| | $p_s$ - Allowable lateral soil pressure at depth $L_e$, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$ $$p_s = 1.425\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.3118\ \mathrm{kip/ft^2}\right)}{\left(1.425\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92054$$ | Status: **PASS**<br>Ratio: **0.920** |
| | **Considering z-direction:**<br>$H_o = 0.033599\ \mathrm{kip/ft}$ - Lateral force per length of pile,<br>$M_o = 0.19252\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,<br>$a$ - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.19252\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.19252\ \mathrm{kipft/ft})) + (4 \times (0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$ $$a = 6.749\ \mathrm{ft}$$ $p$ - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.19252\ \mathrm{kipft/ft})) + (3 \times (0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]^2}{(9.5\ \mathrm{ft})^2 \times [(3 \times (0.19252\ \mathrm{kipft/ft})) + (2 \times (0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}$$ $$p = 0.020399\ \mathrm{kip/ft^2}$$ $s$ - Earth pressure against the pile at distance $L_e$, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.19252\ \mathrm{kipft/ft})) + ((0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}{(9.5\ \mathrm{ft})^2}$$ $$s = 0.046818\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:**<br>$p_a$ - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.749\ \mathrm{ft})}{2}$$ $$p_a = 0.50617\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.020399\ \mathrm{kip/ft^2}\right)}{\left(0.50617\ \mathrm{kip/ft^2}\right)}$$ | |

$$Ratio = 0.0403$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (9.5\ \text{ft})$$

$$p_s = 1.425\ \text{kip/ft}^2$$

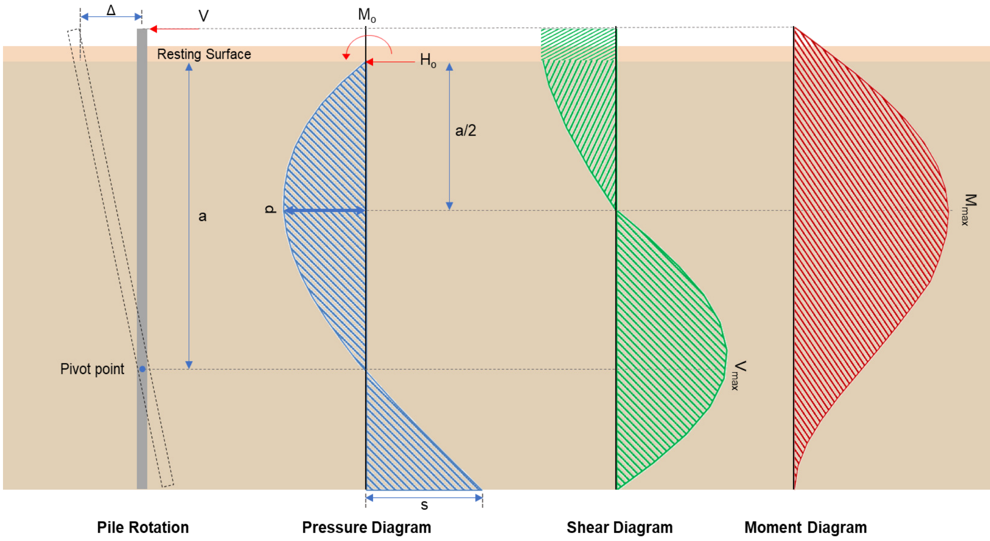
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.046818\ \text{kip/ft}^2)}{(1.425\ \text{kip/ft}^2)}$$

$$Ratio = 0.032855$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-7.035\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.1202\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(138.5\ \text{kipft}) + ((-7.035\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 22.054\ \text{kipft/ft}$$

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

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

$$E = \frac{(22.054\ \text{kipft/ft})}{(-1.1202\ \text{kip/ft})}$$

$$E = 19.687\ \text{ft}$$

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

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

$$a = \frac{(4 \times (22.054\ \text{kipft/ft}) \times (9.5\ \text{ft})) + \left(3 \times (-1.1202\ \text{kip/ft}) \times (9.5\ \text{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (22.054\ \mathrm{kipft/ft})) + (4 \times (-1.1202\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.526\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1202\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.526\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.526\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 19.391\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1202\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (9.5\ \mathrm{ft})) \times \left[\left(\frac{(19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + \frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 88.233\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.364\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.057962\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(2.089\ \mathrm{kipft}) + ((0.364\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.33264\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.33264\ \mathrm{kipft/ft})}{(0.057962\ \mathrm{kip/ft})}$$

$$E = 5.739\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.33264\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (0.057962\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.33264\ \mathrm{kipft/ft})) + (4 \times (0.057962\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.7487\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.057962\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.739\ \text{ft})}{(9.5\ \text{ft})} + 3\right) \times \left(\frac{(6.7487\ \text{ft})}{(9.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.739\ \text{ft})}{(9.5\ \text{ft})} + 2\right) \times \left(\frac{(6.7487\ \text{ft})}{(9.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.40188\ \text{kip}$$

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

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

$$M_{max} = ((0.057962\ \text{kip/ft}) \times (48\ \text{in}) \times (9.5\ \text{ft})) \times \left[\left(\frac{(5.739\ \text{ft})}{(9.5\ \text{ft})} + \frac{(6.7487\ \text{ft})}{2 \times (9.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (5.739\ \text{ft})}{(9.5\ \text{ft})} + 3\right) \times \left(\frac{(6.7487\ \text{ft})}{2 \times (9.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.739\ \text{ft})}{(9.5\ \text{ft})} + 2\right) \times \left(\frac{(6.7487\ \text{ft})}{2 \times (9.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.712\ \text{kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

*22.4.2.2, 10.6.1.1* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.019\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.23\ \text{in}^2$$

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

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

$$A_{min} = Max\left[(-84.23\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: **PASS**
Ratio: **0.970**

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

**Axial Compression Strength (ACI 318-19, LRFD)**

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

$$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.019\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.004119$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

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

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.019\ \text{kip} \rightarrow 11019\ \text{lbf}$,

22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11019\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.95\ \text{kip}$$

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

22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.95\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.95\ \text{kip}$$

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

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.95\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.05\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 19.391\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $$Ratio = \frac{(19.391\ \text{kip})}{(111.05\ \text{kip})}$$ $$Ratio = 0.17461$$ | Status: **PASS**<br>Ratio: **0.170** |
| | **Considering z-direction:**<br>$V_{max} = 0.40188\ \text{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.40188\ \text{kip})}{(111.05\ \text{kip})}$$ $$Ratio = 0.0036189$$ | Status: **PASS**<br>Ratio: **0.000** |
| 14.5.2.1b | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - 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),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:**<br>$M_{max} = 88.233\ \text{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(88.233\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.3535$$ | Status: **PASS**<br>Ratio: **0.350** |
| | **Considering z-direction:**<br>$M_{max} = 1.712\ \text{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{(1.712 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0068588$$ | | Status: **PASS**<br>Ratio: **0.010** |

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

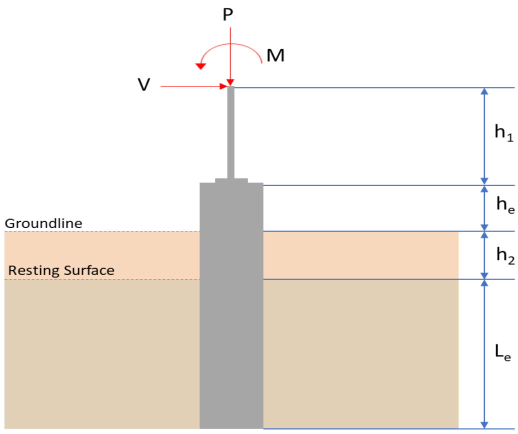
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 9.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure ($q_a$) (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) | 7.869 | 11.019 |
| $V_x$ (kip) | -4.216 | -7.035 |
| $V_z$ (kip) | -0.211 | -0.364 |
| $M_x$ (kipft) | -1.209 | -2.090 |
| $M_z$ (kipft) | 81.982 | 138.501 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.216\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.67134\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(81.982\ \mathrm{kipft}) + ((-4.216\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.054\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 8.8308\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.211\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.033599\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.209\ \mathrm{kipft}) + ((-0.211\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.19252\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.2191\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(8.8308\ \mathrm{ft}), (2.2191\ \mathrm{ft})]$$

$$L_{e,req} = 8.831\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 9.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.831\ \mathrm{ft})}{(9.5\ \mathrm{ft})}$$

$$Ratio = 0.92958$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\ D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.869 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.49181 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.49181 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.24591$$

Status: **PASS**
Ratio: **0.250**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.67134 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 13.054 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.054 \text{ kipft/ft}) \times (9.5 \text{ ft})) + \left(3 \times (-0.67134 \text{ kip/ft}) \times (9.5 \text{ ft})^2\right)}{(6 \times (13.054 \text{ kipft/ft})) + (4 \times (-0.67134 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.5278 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (13.054 \text{ kipft/ft})) + (3 \times (-0.67134 \text{ kip/ft}) \times (9.5 \text{ ft}))]^{\,2}}{(9.5 \text{ ft})^2 \times [(3 \times (13.054 \text{ kipft/ft})) + (2 \times (-0.67134 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = 0.34446 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (13.054 \text{ kipft/ft})) + ((-0.67134 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = 1.3118 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

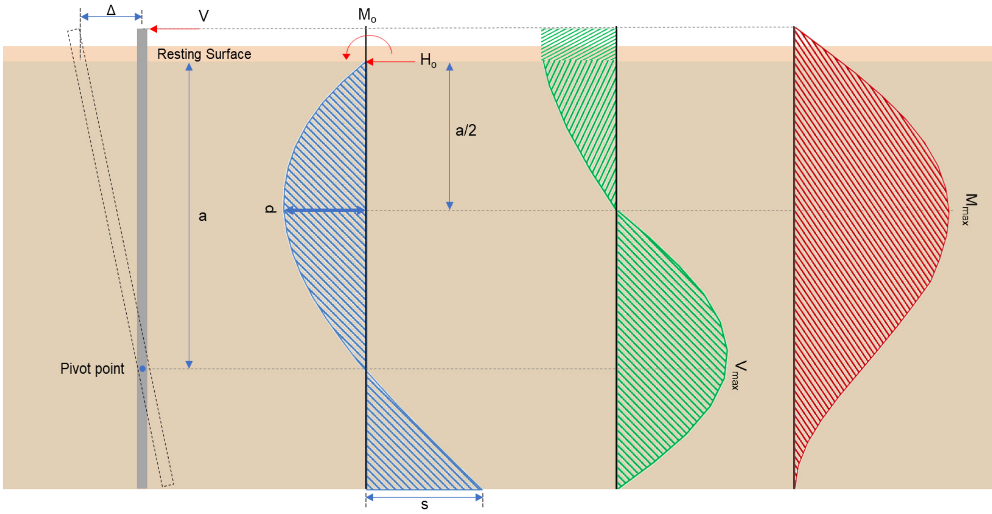
$$p_a = R\, \frac{a}{2}$$

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.5278 \text{ ft})}{2}$$

$$p_a = 0.48959 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.34446\ \mathrm{kip/ft^2}\right)}{\left(0.48959\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.70356$$ $p_s$ - Allowable lateral soil pressure at depth $L_e$, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (9.5\ \mathrm{ft})$$ $$p_s = 1.425\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.3118\ \mathrm{kip/ft^2}\right)}{\left(1.425\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92054$$ | Status: **PASS**<br>Ratio: **0.700**<br><br>Status: **PASS**<br>Ratio: **0.920** |
| | **Considering z-direction:**<br>$H_o = -0.033599\ \mathrm{kip/ft}$ - Lateral force per length of pile,<br>$M_o = 0.19252\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,<br>$a$ - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.19252\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (-0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.19252\ \mathrm{kipft/ft})) + (4 \times (-0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$ $$a = 6.749\ \mathrm{ft}$$ $p$ - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.19252\ \mathrm{kipft/ft})) + (3 \times (-0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]^{\ 2}}{(9.5\ \mathrm{ft})^2 \times [(3 \times (0.19252\ \mathrm{kipft/ft})) + (2 \times (-0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}$$ $$p = -0.004803\ \mathrm{kip/ft^2}$$ $s$ - Earth pressure against the pile at distance $L_e$, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.19252\ \mathrm{kipft/ft})) + ((-0.033599\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))]}{(9.5\ \mathrm{ft})^2}$$ $$s = 0.0043774\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:**<br>$p_a$ - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.749\ \mathrm{ft})}{2}$$ $$p_a = 0.50617\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.004803\ \mathrm{kip/ft^2}\right)}{\left(0.50617\ \mathrm{kip/ft^2}\right)}$$ | |

| | | |
|---|---|---|
| | $$Ratio = -0.0094889$$ | Status: **PASS** Ratio: **-0.010** |
| | $p_s$ - Allowable lateral soil pressure at depth $L_e$, $$p_s = R\, L_e$$ $$p_s = (150\ \text{psf/ft}) \times (9.5\ \text{ft})$$ $$p_s = 1.425\ \text{kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(0.0043774\ \text{kip/ft}^2)}{(1.425\ \text{kip/ft}^2)}$$ $$Ratio = 0.0030719$$ | Status: **PASS** Ratio: **0.000** |
| |   Pile Rotation Pressure Diagram Shear Diagram Moment Diagram **Shear force and Bending moment (x-direction, LRFD)** $H_o$ - Lateral force per length of pile, $$H_o = \frac{V_x}{1.57\, D}$$ $$H_o = \frac{(-7.035\ \text{kip})}{1.57 \times (48\ \text{in})}$$ $$H_o = -1.1202\ \text{kip/ft}$$ $M_o$ - Moment per length of pile, $$M_o = \frac{M_z + (V_x\, H)}{1.57\, D}$$ $$M_o = \frac{(138.5\ \text{kipft}) + ((-7.035\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$ $$M_o = 22.054\ \text{kipft/ft}$$ $E$ - Distance from lateral load to resisting surface, $$E = \frac{M_o}{H_o}$$ $$E = \frac{(22.054\ \text{kipft/ft})}{(-1.1202\ \text{kip/ft})}$$ $$E = 19.687\ \text{ft}$$ $a$ - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (22.054\ \text{kipft/ft}) \times (9.5\ \text{ft})) + \left(3 \times (-1.1202\ \text{kip/ft}) \times (9.5\ \text{ft})^2\right)}{}$$ | |

$$a = \frac{}{(6 \times (22.054\ \mathrm{kipft/ft})) + (4 \times (-1.1202\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.526\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1202\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.526\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.526\ \mathrm{ft})}{(9.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 19.391\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1202\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (9.5\ \mathrm{ft})) \times \left[\left(\frac{(19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + \frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.687\ \mathrm{ft})}{(9.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.526\ \mathrm{ft})}{2 \times (9.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 88.233\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.364\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.057962\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(2.09\ \mathrm{kipft}) + ((-0.364\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.3328\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.3328\ \mathrm{kipft/ft})}{(-0.057962\ \mathrm{kip/ft})}$$

$$E = 5.7418\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.3328\ \mathrm{kipft/ft}) \times (9.5\ \mathrm{ft})) + \left(3 \times (-0.057962\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft})^2\right)}{(6 \times (0.3328\ \mathrm{kipft/ft})) + (4 \times (-0.057962\ \mathrm{kip/ft}) \times (9.5\ \mathrm{ft}))}$$

$$a = 6.7486\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.057962 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.7418 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.7486 \text{ ft})}{(9.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.7418 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.7486 \text{ ft})}{(9.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.402 \text{ kip}$$

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

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

$$M_{max} = ((-0.057962 \text{ kip/ft}) \times (48 \text{ in}) \times (9.5 \text{ ft})) \times \left[\left(\frac{(5.7418 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.7486 \text{ ft})}{2 \times (9.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.7418 \text{ ft})}{(9.5 \text{ ft})} + 3\right) \times \left(\frac{(6.7486 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.7418 \text{ ft})}{(9.5 \text{ ft})} + 2\right) \times \left(\frac{(6.7486 \text{ ft})}{2 \times (9.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.7125 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.019 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.23 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-84.23 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: **PASS**
Ratio: **0.970**

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

**Axial Compression Strength (ACI 318-19, LRFD)**

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

$$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.019\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.004119$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

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

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.019 \text{ kip} \rightarrow 11019 \text{ lbf}$,

22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11019 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.95 \text{ kip}$$

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

22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.95 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.95 \text{ kip}$$

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

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((119.95 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.05 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 19.391 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $$Ratio = \frac{(19.391 \text{ kip})}{(111.05 \text{ kip})}$$ $$Ratio = 0.17461$$ | Status: **PASS**<br>Ratio: **0.170** |
| | **Considering z-direction:**<br>$V_{max} = 0.402 \text{ kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.402 \text{ kip})}{(111.05 \text{ kip})}$$ $$Ratio = 0.0036199$$ | Status: **PASS**<br>Ratio: **0.000** |
| *14.5.2.1b* | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - 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),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:**<br>$M_{max} = 88.233 \text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(88.233 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.3535$$ | Status: **PASS**<br>Ratio: **0.350** |
| | **Considering z-direction:**<br>$M_{max} = 1.7125 \text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | |
|---|---|---|
| | $$Ratio = \frac{(1.7125\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.006861$$ | Status: **PASS**<br>Ratio: **0.010** |

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

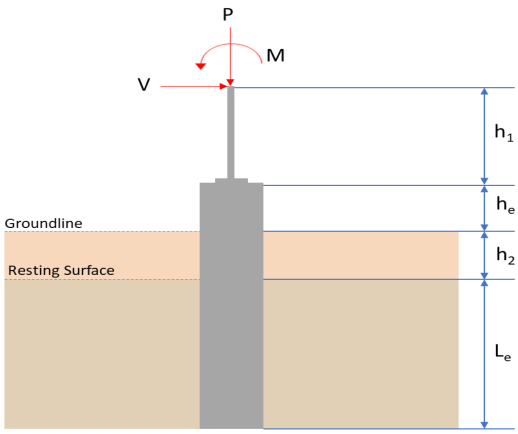
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 9.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure $(q_a)$ (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) | 9.438 | 13.400 |
| $V_x$ (kip) | -4.957 | -8.258 |
| $V_z$ (kip) | -0.021 | -0.036 |
| $M_x$ (kipft) | -0.122 | -0.217 |
| $M_z$ (kipft) | 96.737 | 163.936 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.957\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.78933\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(96.737\ \text{kipft}) + ((-4.957\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 15.404\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 9.2592\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.021\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0033439\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.122\ \text{kipft}) + ((-0.021\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.019427\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.1008\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(9.2592\ \text{ft}), (1.1008\ \text{ft})]$$

$$L_{e,req} = 9.259\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.259\ \text{ft})}{(9.75\ \text{ft})}$$

$$Ratio = 0.94964$$

Status: **PASS**
Ratio: **0.950**

**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

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

$$q = \frac{(9.438\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.58988\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.58988\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.29494$$

Status: **PASS**
Ratio: **0.290**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.4375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.78933\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 15.404\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.404\ \mathrm{kipft/ft}) \times (9.75\ \mathrm{ft})) + \left(3 \times (-0.78933\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft})^2\right)}{(6 \times (15.404\ \mathrm{kipft/ft})) + (4 \times (-0.78933\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))}$$

$$a = 6.703\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (15.404\ \mathrm{kipft/ft})) + (3 \times (-0.78933\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]^2}{(9.75\ \mathrm{ft})^2 \times [(3 \times (15.404\ \mathrm{kipft/ft})) + (2 \times (-0.78933\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}$$

$$p = 0.38\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (15.404\ \mathrm{kipft/ft})) + ((-0.78933\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}{(9.75\ \mathrm{ft})^2}$$

$$s = 1.4587\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.703\ \mathrm{ft})}{2}$$

$$p_a = 0.50273\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.38\ \mathrm{kip/ft^2}\right)}{\left(0.50273\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.75586$$ $p_s$ - Allowable lateral soil pressure at depth $L_e$, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (9.75\ \mathrm{ft})$$ $$p_s = 1.4625\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.4587\ \mathrm{kip/ft^2}\right)}{\left(1.4625\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.99743$$ | Status: **PASS**<br>Ratio: **0.760**<br><br>Status: **PASS**<br>Ratio: **1.000** | |
| | **Considering z-direction:** $H_o = -0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,<br>$M_o = 0.019427\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,<br>$a$ - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.019427\ \mathrm{kipft/ft}) \times (9.75\ \mathrm{ft})) + \left(3 \times (-0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft})^2\right)}{(6 \times (0.019427\ \mathrm{kipft/ft})) + (4 \times (-0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))}$$ $$a = 6.929\ \mathrm{ft}$$ $p$ - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.019427\ \mathrm{kipft/ft})) + (3 \times (-0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]^{\ 2}}{(9.75\ \mathrm{ft})^2 \times [(3 \times (0.019427\ \mathrm{kipft/ft})) + (2 \times (-0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}$$ $$p = -0.00046033\ \mathrm{kip/ft^2}$$ $s$ - Earth pressure against the pile at distance $L_e$, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.019427\ \mathrm{kipft/ft})) + ((-0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}{(9.75\ \mathrm{ft})^2}$$ $$s = 0.00039448\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** $p_a$ - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.929\ \mathrm{ft})}{2}$$ $$p_a = 0.51968\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.00046033\ \mathrm{kip/ft^2}\right)}{\left(0.51968\ \mathrm{kip/ft^2}\right)}$$ | | |

$$Ratio = -0.00088579$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.75\ \mathrm{ft})$$

$$p_s = 1.4625\ \mathrm{kip/ft^2}$$

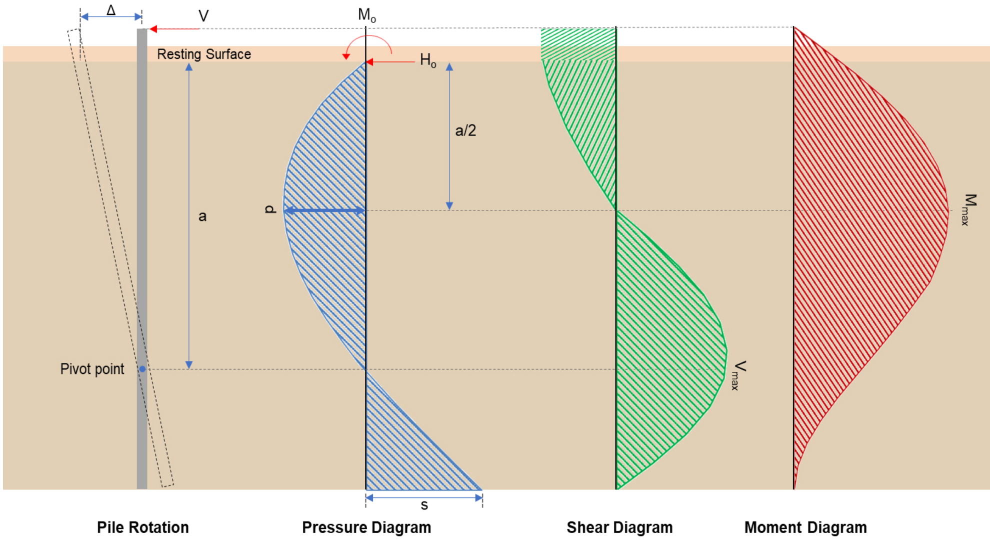
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00039448\ \mathrm{kip/ft^2}\right)}{\left(1.4625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00026973$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-8.258\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.315\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(163.94\ \mathrm{kipft}) + ((-8.258\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 26.104\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(26.104\ \mathrm{kipft/ft})}{(-1.315\ \mathrm{kip/ft})}$$

$$E = 19.852\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (26.104\ \mathrm{kipft/ft}) \times (9.75\ \mathrm{ft})) + \left(3 \times (-1.315\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (26.104\ \text{kipft/ft})) + (4 \times (-1.315\ \text{kip/ft}) \times (9.75\ \text{ft}))}$$

$$a = 6.7004\ \text{ft}$$

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

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

$$V_{max} = ((-1.315\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 3\right) \times \left(\frac{(6.7004\ \text{ft})}{(9.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 2\right) \times \left(\frac{(6.7004\ \text{ft})}{(9.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 22.424\ \text{kip}$$

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

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

$$M_{max} = ((-1.315\ \text{kip/ft}) \times (48\ \text{in}) \times (9.75\ \text{ft})) \times \left[\left(\frac{(19.852\ \text{ft})}{(9.75\ \text{ft})} + \frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 3\right) \times \left(\frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 2\right) \times \left(\frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 104.65\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.036\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0057325\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.217\ \text{kipft}) + ((-0.036\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.034554\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.034554\ \text{kipft/ft})}{(-0.0057325\ \text{kip/ft})}$$

$$E = 6.0278\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.034554\ \text{kipft/ft}) \times (9.75\ \text{ft})) + \left(3 \times (-0.0057325\ \text{kip/ft}) \times (9.75\ \text{ft})^2\right)}{(6 \times (0.034554\ \text{kipft/ft})) + (4 \times (-0.0057325\ \text{kip/ft}) \times (9.75\ \text{ft}))}$$

$$a = 6.9216\ \text{ft}$$

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

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

| | | |
|---|---|---|
| | $$V_{max} = ((-0.0057325 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.0278 \text{ ft})}{(9.75 \text{ ft})} + 3\right) \times \left(\frac{(6.9216 \text{ ft})}{(9.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.0278 \text{ ft})}{(9.75 \text{ ft})} + 2\right) \times \left(\frac{(6.9216 \text{ ft})}{(9.75 \text{ ft})}\right)^3\right]\right]$$ $$V_{max} = 0.040314 \text{ kip}$$ $M_{max}$ - Max bending moment located at depth a/2, $$M_{max} = (H_o\, b\, L_e)\left[\left(\frac{E}{L_e} + \frac{a}{2\,L_e}\right) - \left[\left(\frac{4\,E}{L_e} + 3\right)\left(\frac{a}{2\,L_e}\right)^3\right] + \left[\left(\frac{3\,E}{L_e} + 2\right)\left(\frac{a}{2\,L_e}\right)^4\right]\right]$$ $$M_{max} = ((-0.0057325 \text{ kip/ft}) \times (48 \text{ in}) \times (9.75 \text{ ft})) \times \left[\left(\frac{(6.0278 \text{ ft})}{(9.75 \text{ ft})} + \frac{(6.9216 \text{ ft})}{2 \times (9.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (6.0278 \text{ ft})}{(9.75 \text{ ft})} + 3\right) \times \left(\frac{(6.9216 \text{ ft})}{2 \times (9.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.0278 \text{ ft})}{(9.75 \text{ ft})} + 2\right) \times \left(\frac{(6.9216 \text{ ft})}{2 \times (9.75 \text{ ft})}\right)^4\right]\right]$$ $$M_{max} = 0.17653 \text{ kipft}$$ | |
| Table 22.4.2.1<br>22.4.2.2, 10.6.1.1 | **Minimum Reinforcement Check (LRFD)**<br>**Parameters:**<br>$f'_{ck} = 2.5$ ksi - Concrete strength,<br>$f_{yk} = 60$ ksi - Longitudinal reinforcement strength,<br>$\phi = 0.65$ - Reduction factor for axial strength,<br>$\alpha = 0.8$ - Alpha factor for axial strength,<br>$A_g = 2304$ in$^2$ - Gross area of concrete,<br>**Longitudinal reinforcement:**<br>Required reinforcement due to axial load, $A_{st,required}$<br>$A_{st,required}$ $$A_{st,required} = Min\left[\frac{\frac{P}{\phi\,\alpha} - (0.85\, f'_{ck}\, A_g)}{f_{yk} - (0.85\, f'_{ck})}, (0.08\, A_g)\right]$$ $$A_{st,required} = Min\left[\frac{\frac{(13.4 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$ $$A_{st,required} = -84.151 \text{ in}^2$$ $A_{min}$ - Governing minimum reinforcement area, $$A_{min} = Max\left[A_{st,required}, (0.0018\, A_g)\right]$$ $$A_{min} = Max\left[(-84.151 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$ $$A_{min} = 4.1472 \text{ in}^2$$ $n_{rebar}$ - Required number of reinforcement, $$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$ $$n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$ $$n_{rebar} = 14$$ $A_{st}$ - Actual total reinforcement area, $$A_{st} = n_{rebar}\,\frac{\pi\, d_{bar}^2}{4}$$ $$A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$ $$A_{st} = 4.2951 \text{ in}^2$$ $Ratio$ - Capacity $$Ratio = \frac{A_{min}}{A_{st}}$$ $$Ratio = \frac{(4.1472 \text{ in}^2)}{(4.2951 \text{ in}^2)}$$ | |

$$Ratio = 0.96556$$

Status: **PASS**
Ratio: **0.970**

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

**Axial Compression Strength (ACI 318-19, LRFD)**

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

$$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.4\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.005009$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.64282$$

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

22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ , $P = 13.4 \text{ kip} \rightarrow 13400 \text{ lbf}$ ,

*22.5.5.1.1(a)* $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13400 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.27 \text{ kip}$$

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

*22.5.5.1.2* $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.27 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.27 \text{ kip}$$

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

*22.5.1.2* $V_{s,a}$ - Shear strength of steel (a)

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

*22.5.1.1* $\phi V_n$ - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.27 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.26 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 22.424 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{(22.424\ \mathrm{kip})}{(111.26\ \mathrm{kip})}$$ $$Ratio = 0.20155$$ | Status: **PASS**<br>Ratio: **0.200** |
| | **Considering z-direction:**<br>$V_{max} = 0.040314\ \mathrm{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.040314\ \mathrm{kip})}{(111.26\ \mathrm{kip})}$$ $$Ratio = 0.00036235$$ | Status: **PASS**<br>Ratio: **0.000** |
| 14.5.2.1b | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:**<br>$M_{max} = 104.65\ \mathrm{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(104.65\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.41927$$ | Status: **PASS**<br>Ratio: **0.420** |
| | **Considering z-direction:**<br>$M_{max} = 0.17653\ \mathrm{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | | |
|---|---|---|---|
| | | $$Ratio = \frac{(0.17653 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00070726$$ | Status: **PASS**<br>Ratio: **0.000** |

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

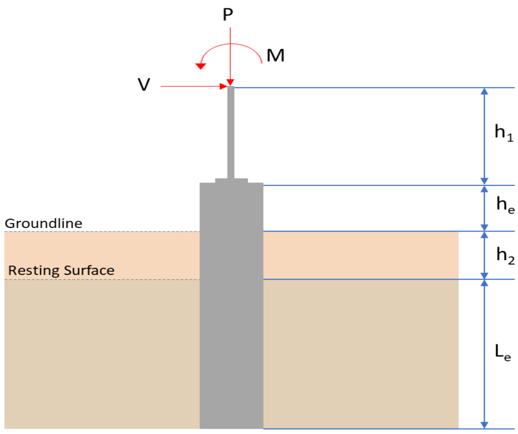
## SkyCiv Foundation Design

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
$L = 9.75$ 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) | 9.438 | 13.400 |
| $V_x$ (kip) | -4.957 | -8.258 |
| $V_z$ (kip) | 0.021 | 0.036 |
| $M_x$ (kipft) | 0.122 | 0.218 |
| $M_z$ (kipft) | 96.737 | 163.936 |

**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,

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

$$H_o = \frac{(-4.957 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.78933 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(96.737\ \text{kipft}) + ((-4.957\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 15.404\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 9.2592\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.021\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0033439\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.122\ \text{kipft}) + ((0.021\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.019427\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.216\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(9.2592\ \text{ft}), (1.216\ \text{ft})]$$

$$L_{e,req} = 9.259\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(9.259\ \text{ft})}{(9.75\ \text{ft})}$$

$$Ratio = 0.94964$$

Status: **PASS**
Ratio: **0.950**

**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

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

$$q = \frac{(9.438\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.58988\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.58988\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.29494$$

Status: **PASS**
Ratio: **0.290**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.4375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.78933\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 15.404\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.404\ \text{kipft/ft}) \times (9.75\ \text{ft})) + \left(3 \times (-0.78933\ \text{kip/ft}) \times (9.75\ \text{ft})^2\right)}{(6 \times (15.404\ \text{kipft/ft})) + (4 \times (-0.78933\ \text{kip/ft}) \times (9.75\ \text{ft}))}$$

$$a = 6.703\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (15.404\ \text{kipft/ft})) + (3 \times (-0.78933\ \text{kip/ft}) \times (9.75\ \text{ft}))]^2}{(9.75\ \text{ft})^2 \times [(3 \times (15.404\ \text{kipft/ft})) + (2 \times (-0.78933\ \text{kip/ft}) \times (9.75\ \text{ft}))]}$$

$$p = 0.38\ \text{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (15.404\ \text{kipft/ft})) + ((-0.78933\ \text{kip/ft}) \times (9.75\ \text{ft})]}{(9.75\ \text{ft})^2}$$

$$s = 1.4587\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.703\ \text{ft})}{2}$$

$$p_a = 0.50273\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.38\ \mathrm{kip/ft^2}\right)}{\left(0.50273\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.75586$$

Status: **PASS**
Ratio: **0.760**

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

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.75\ \mathrm{ft})$$

$$p_s = 1.4625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.4587\ \mathrm{kip/ft^2}\right)}{\left(1.4625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.99743$$

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

**Considering z-direction:**

$H_o = 0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.019427\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019427\ \mathrm{kipft/ft}) \times (9.75\ \mathrm{ft})) + \left(3 \times (0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft})^2\right)}{(6 \times (0.019427\ \mathrm{kipft/ft})) + (4 \times (0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))}$$

$$a = 6.929\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.019427\ \mathrm{kipft/ft})) + (3 \times (0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]^{\,2}}{(9.75\ \mathrm{ft})^2 \times [(3 \times (0.019427\ \mathrm{kipft/ft})) + (2 \times (0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}$$

$$p = 0.0019682\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.019427\ \mathrm{kipft/ft})) + ((0.0033439\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft}))]}{(9.75\ \mathrm{ft})^2}$$

$$s = 0.0045101\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.929\ \mathrm{ft})}{2}$$

$$p_a = 0.51968\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0019682\ \mathrm{kip/ft^2}\right)}{\left(0.51968\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0037874$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (9.75\ \mathrm{ft})$$

$$p_s = 1.4625\ \mathrm{kip/ft^2}$$

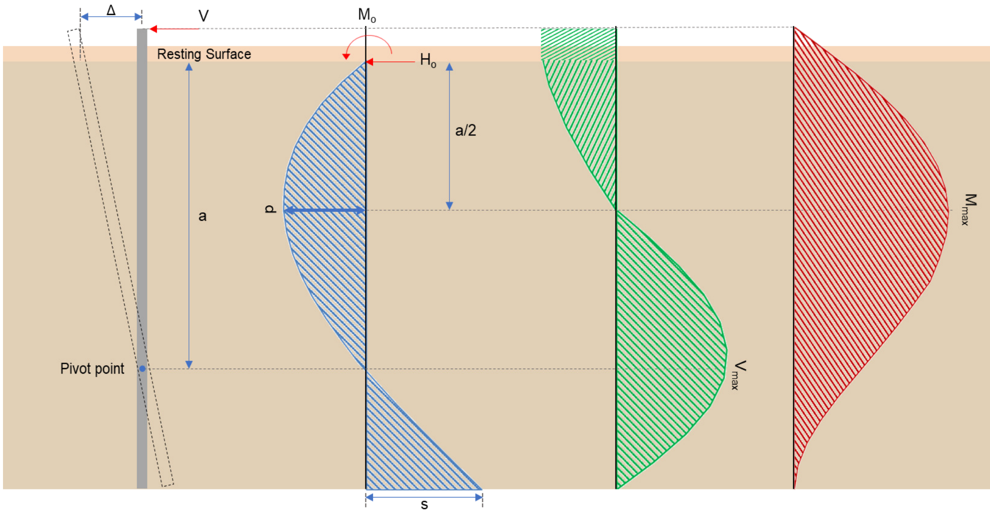
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0045101\ \mathrm{kip/ft^2})}{(1.4625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0030838$$

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




Pile Rotation | Pressure Diagram | Shear Diagram | Moment Diagram

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-8.258\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.315\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(163.94\ \mathrm{kipft}) + ((-8.258\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 26.104\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(26.104\ \mathrm{kipft/ft})}{(-1.315\ \mathrm{kip/ft})}$$

$$E = 19.852\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (26.104\ \mathrm{kipft/ft}) \times (9.75\ \mathrm{ft})) + \left(3 \times (-1.315\ \mathrm{kip/ft}) \times (9.75\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (26.104\ \text{kipft/ft})) + (4 \times (-1.315\ \text{kip/ft}) \times (9.75\ \text{ft}))}$$

$$a = 6.7004\ \text{ft}$$

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

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

$$V_{max} = ((-1.315\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 3\right) \times \left(\frac{(6.7004\ \text{ft})}{(9.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 2\right) \times \left(\frac{(6.7004\ \text{ft})}{(9.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 22.424\ \text{kip}$$

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

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

$$M_{max} = ((-1.315\ \text{kip/ft}) \times (48\ \text{in}) \times (9.75\ \text{ft})) \times \left[\left(\frac{(19.852\ \text{ft})}{(9.75\ \text{ft})} + \frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 3\right) \times \left(\frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (19.852\ \text{ft})}{(9.75\ \text{ft})} + 2\right) \times \left(\frac{(6.7004\ \text{ft})}{2 \times (9.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 104.65\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.036\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0057325\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.218\ \text{kipft}) + ((0.036\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.034713\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.034713\ \text{kipft/ft})}{(0.0057325\ \text{kip/ft})}$$

$$E = 6.0556\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.034713\ \text{kipft/ft}) \times (9.75\ \text{ft})) + \left(3 \times (0.0057325\ \text{kip/ft}) \times (9.75\ \text{ft})^2\right)}{(6 \times (0.034713\ \text{kipft/ft})) + (4 \times (0.0057325\ \text{kip/ft}) \times (9.75\ \text{ft}))}$$

$$a = 6.9206\ \text{ft}$$

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

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

$$V_{max} = ((0.0057325\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (6.0556\ \mathrm{ft})}{(9.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.9206\ \mathrm{ft})}{(9.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (6.0556\ \mathrm{ft})}{(9.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.9206\ \mathrm{ft})}{(9.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.040429\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0057325\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (9.75\ \mathrm{ft})) \times \left[\left(\frac{(6.0556\ \mathrm{ft})}{(9.75\ \mathrm{ft})} + \frac{(6.9206\ \mathrm{ft})}{2 \times (9.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (6.0556\ \mathrm{ft})}{(9.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.9206\ \mathrm{ft})}{2 \times (9.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (6.0556\ \mathrm{ft})}{(9.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.9206\ \mathrm{ft})}{2 \times (9.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.17709\ \mathrm{kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

*22.4.2.2, 10.6.1.1* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.4\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.151\ \mathrm{in}^2$$

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

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

$$A_{min} = Max\left[(-84.151\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

| | | |
|---|---|---|
| | $$Ratio = 0.96556$$ | Status: **PASS** Ratio: **0.970** |
| 25.2.3 | $s_{rebar}$ - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, (1.5\ d_{bar})\right]$$ $$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\ \text{in}))\right]$$ $$s_{rebar} = 1.5\ \text{in}$$ | |
| | **Ties:** | |
| 25.7.2.2<br>25.7.2.1 | Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)<br>$s_{ties}$ - Maximum spacing of ties, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min\,((48\ \text{in}), (48\ \text{in}))\right]$$ $$s_{ties} = 10\ \text{in}$$ | |
| | **Summary:**<br>Main reinforcement: **14 - #5 (0.625 in)**<br>Ties: **#3(0.375 in) - 10 in** | |
| 22.4.2.2 | **Axial Compression Strength (ACI 318-19, LRFD)**<br>$\phi P_N$ - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.4\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.005009$$ | Status: **PASS** Ratio: **0.010** |
| 22.5.2.2<br>22.5.5.1.3<br>22.5.5.1.1 | **Shear Strength (ACI 318-19, LRFD)**<br>**Parameters:**<br>$b_w = 48\ \text{in}$ - Effective width,<br>$d$ - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ $\lambda_s$ - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,<br>$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ | |

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.4 \text{ kip} \rightarrow 13400 \text{ lbf}$,

*22.5.5.1.1(a)* $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13400 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.27 \text{ kip}$$

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

*22.5.5.1.2* $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.27 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.27 \text{ kip}$$

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

*22.5.1.2* $V_{s,a}$ - Shear strength of steel (a)

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

*22.5.1.1* $\phi V_n$ - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.27 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.26 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 22.424 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $$Ratio = \frac{(22.424\ \mathrm{kip})}{(111.26\ \mathrm{kip})}$$ $$Ratio = 0.20155$$ | Status: **PASS**<br>Ratio: **0.200** |
| | **Considering z-direction:**<br>$V_{max} = 0.040429\ \mathrm{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.040429\ \mathrm{kip})}{(111.26\ \mathrm{kip})}$$ $$Ratio = 0.00036338$$ | Status: **PASS**<br>Ratio: **0.000** |
| 14.5.2.1b | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:**<br>$M_{max} = 104.65\ \mathrm{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(104.65\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.41927$$ | Status: **PASS**<br>Ratio: **0.420** |
| | **Considering z-direction:**<br>$M_{max} = 0.17709\ \mathrm{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | |
|---|---|---|
| | $$Ratio = \frac{(0.17709 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0007095$$ | Status: **PASS**<br>Ratio: **0.000** |