# Project Details

**Project Name:** Winthrop 4x12-50D-8ft

**Location:** 7831 Farm to Market Rd, Whitefish, MT 59937, USA

**Unique ID:** 4P-22.5-8TOP-XD-57-L-4Hx12W-ALKE

**Dealer:** ______________________________

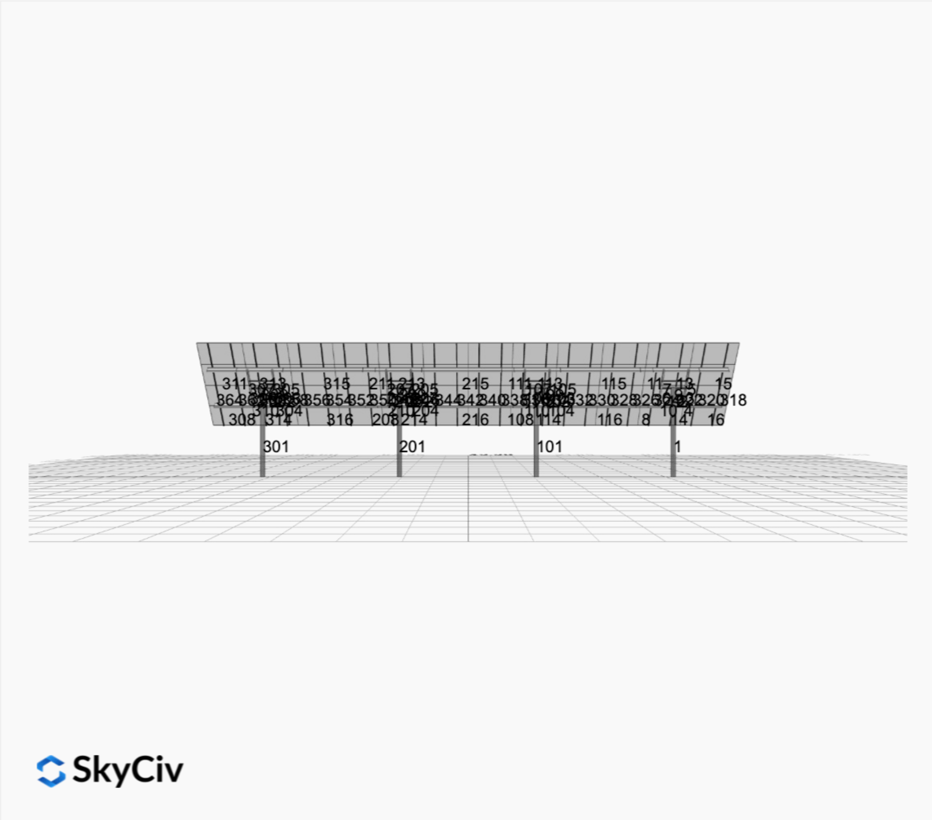
**Date:** Mon Sep 29 2025

**Number of Modules:** 48

**Number of Poles:** 4

**Date Sold:**

______________________________




| | |
|---|---|
| **Array Dimensions N/S** | 17.30 ft |
| **Array Dimensions E/W** | 86.60 ft |
| **Winter Tilt Angle** | 50 |
| **Front Edge Clearance** | 8 ft |

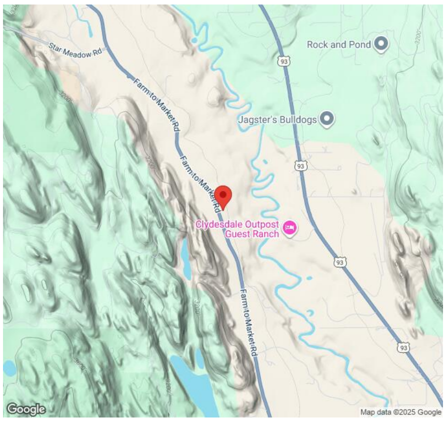
### MT Solar Bill of Materials (4P-22.5-8TOP-XD-57-L-4Hx12W-ALKE)

| Part | Short Description | BOM Qty |
|---|---|---|
| MTS-PC-8 | 8IN Pole Cap Assembly | 4 |
| MTS-HF-XD | H-Frame Assembly-XD | 4 |
| MTS-XD-Wing-57 | 57IN XD Wing | 4 |
| MTS-XD-Splice-90 | 90IN XD Splice | 12 |
| MTS-CLAMP-HOOK-4PK | Hook Clamp | 12 |

### Rail Bill of Materials

| Part | Qty |
|---|---|
| Rails (208in) | 24 |
| Rail Attachment | 48 |
| Module Mid Clamp | 72 |
| Module End Clamp | 48 |
| Ground Lug | 12 |

# Site Details:




**Site Address:** 7831 Farm to Market Rd, Whitefish, MT 59937, USA

### Array Specification

| | |
|---|---|
| **Duty Classification:** | XD |
| **Module Width:** | 51.40 in |
| **Module Length:** | 85.60in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 12 |
| **Total Number of Modules:** | 48 |
| **Winter Tilt Angle:** | 50 |
| **Front Edge Clearance:** | 8 |
| **Total Array Height at Tilt:** | 21.25 ft |
| **Total Frame Length:** | 84.50 ft |
| **Module Info/Notes:** | |
| **Array Dimensions N/S:** | 17.30 ft |
| **Array Dimensions E/W:** | 86.60 ft |
| **Rail Length:** | 207.60 in |
| **Rail Spacing:** | 3.61 ft |

### Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 80 |
| **Pole Length above Grade:** | 14.63 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: 8.25 ft<br>Pile 2: 8.50 ft<br>Pile 3: 8.50 ft<br>Pile 4: 8.25 ft |
| **Foundation Volume:** | 19.852 $y^3$ |

### Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 7831 Farm to Market Rd, Whitefish, MT 59937, USA |
| **Wind Speed:** | 110 mph |

| | |
|---|---|
| **Snow Load:** | 85 psf |

### Design Disclaimer

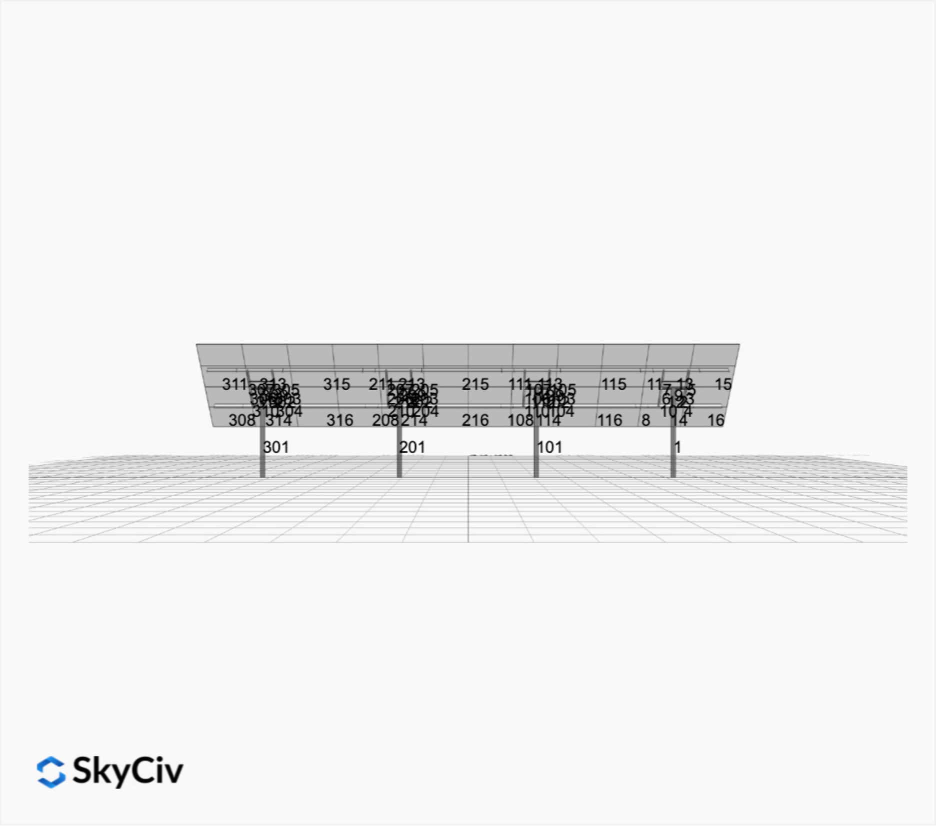
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

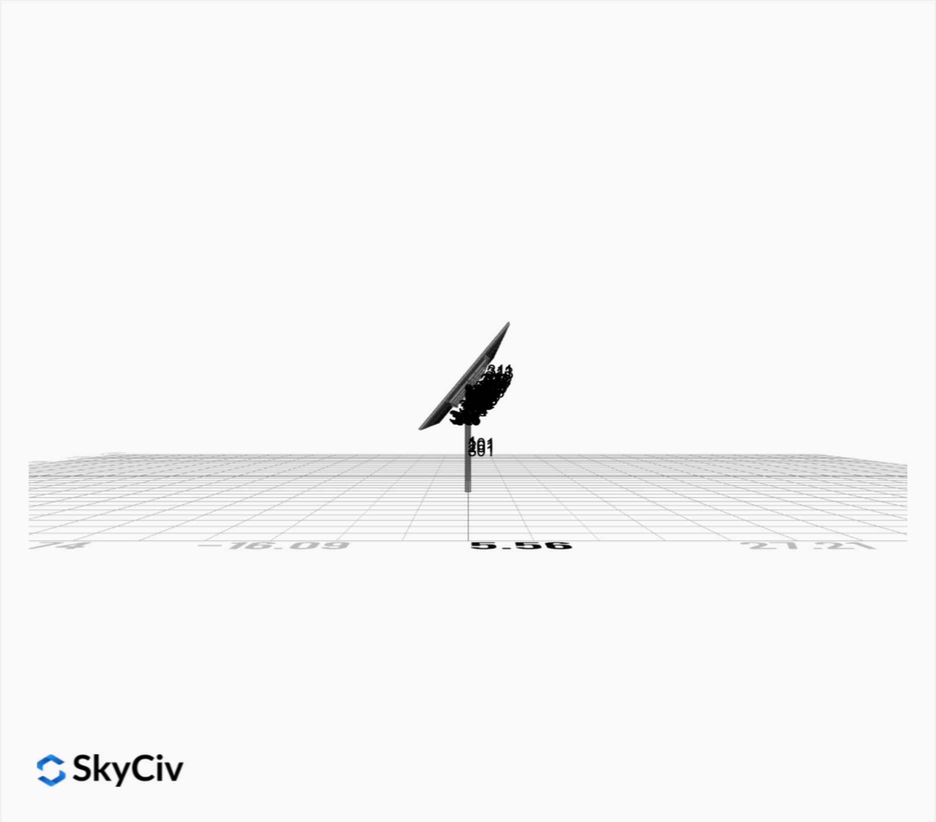
### AutoDesigner Input

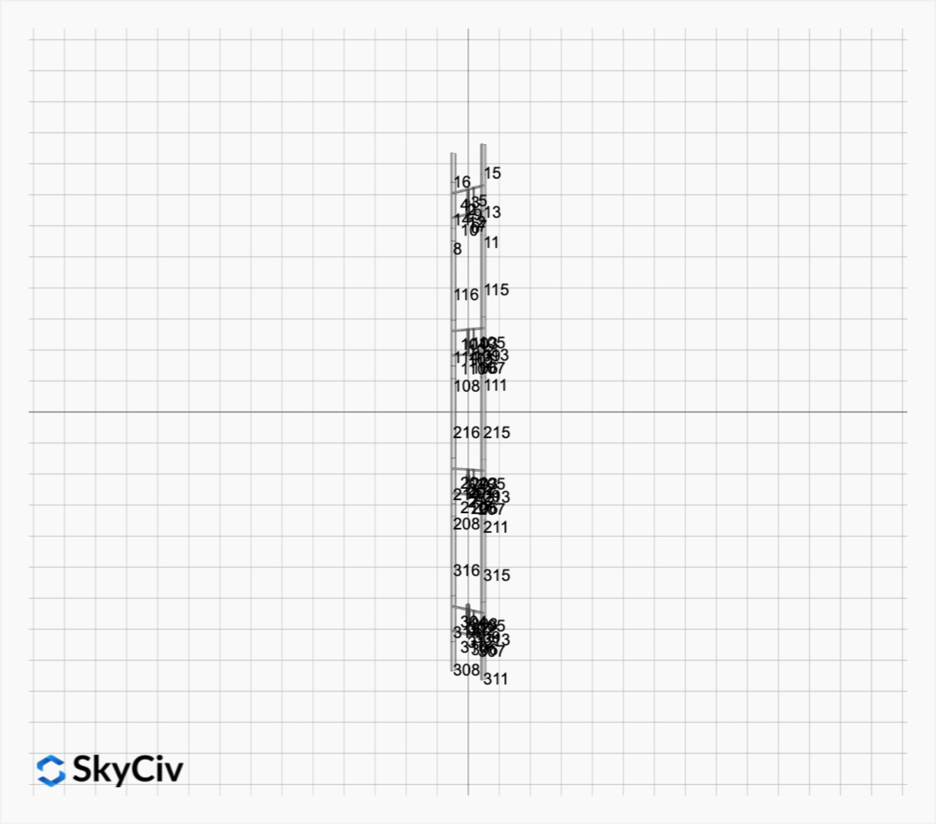
{"wind_speed_override":110,"snow_load_override":85,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"","designer_phone":"","project_id":"Winthrop 4x12-50D-8ft","site_address":"7831 Farm to Market Rd, Whitefish, MT 59937, USA","module_info":"","module_width":51.4,"module_length":85.6,"number_rows":"4","number_columns":12,"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":8,"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":true}

**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)




5.56
-16.09
SkyCiv


16
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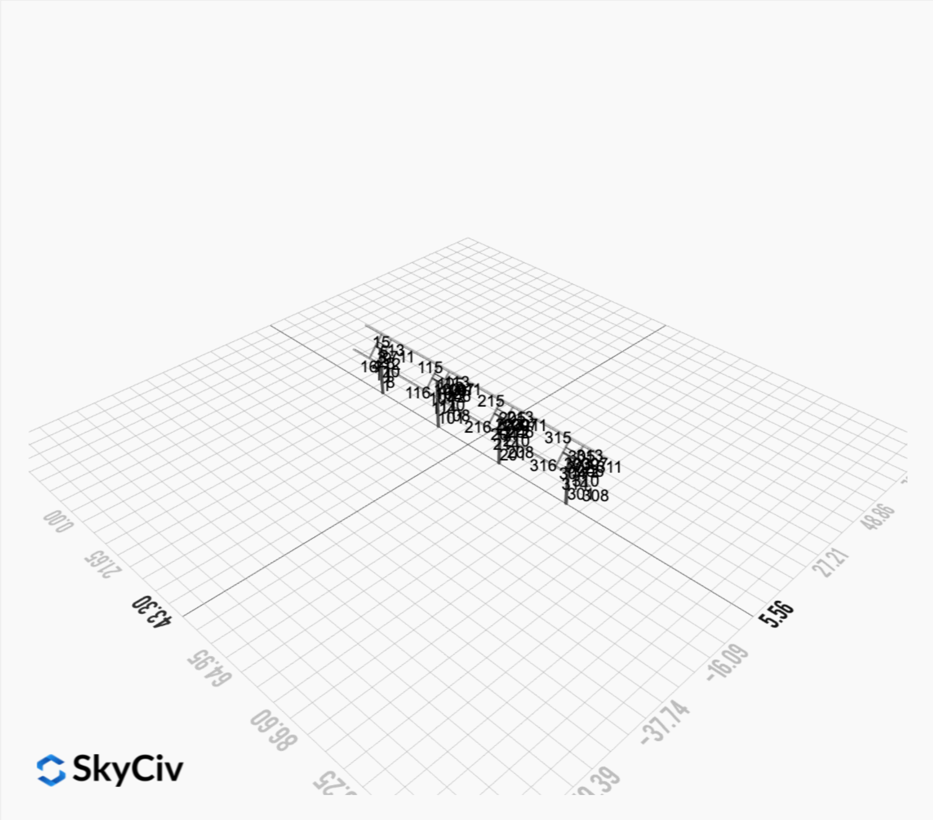
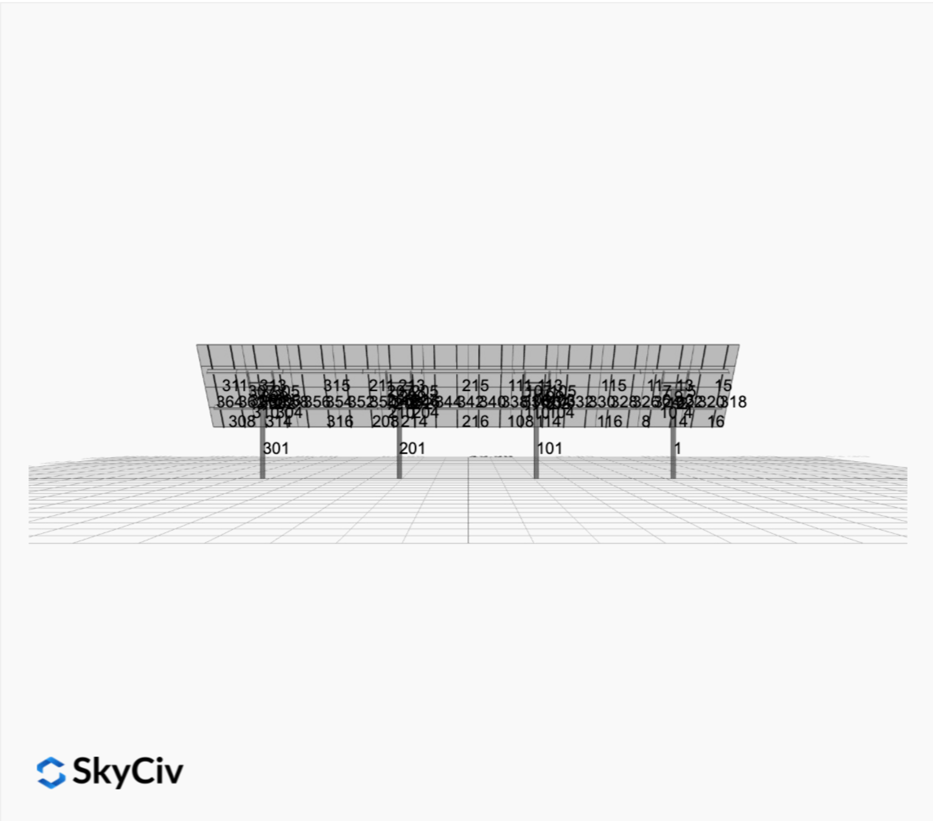
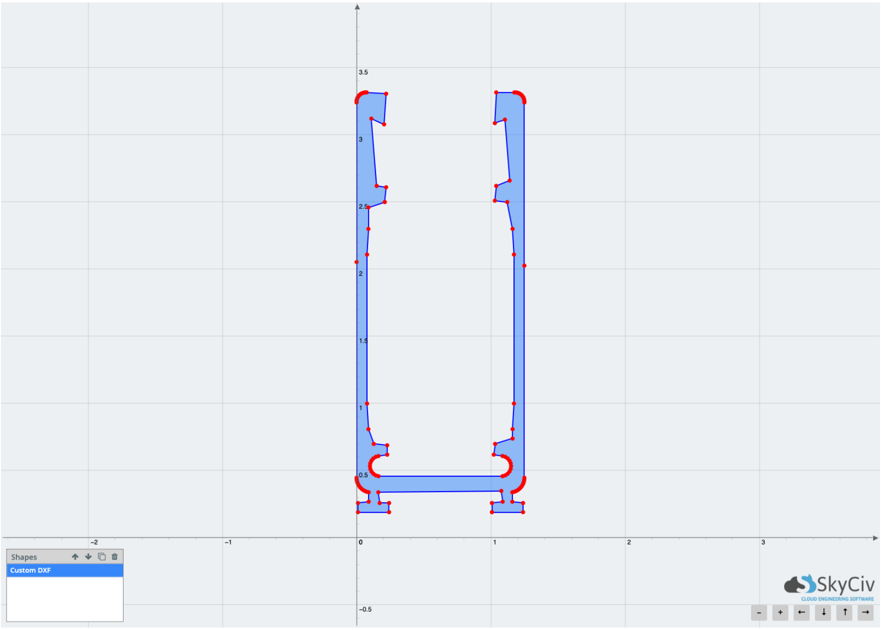

0.00
21.65
43.30
64.95
86.60
5.56
21.21
48.86
-16.09
-37.74
SkyCiv

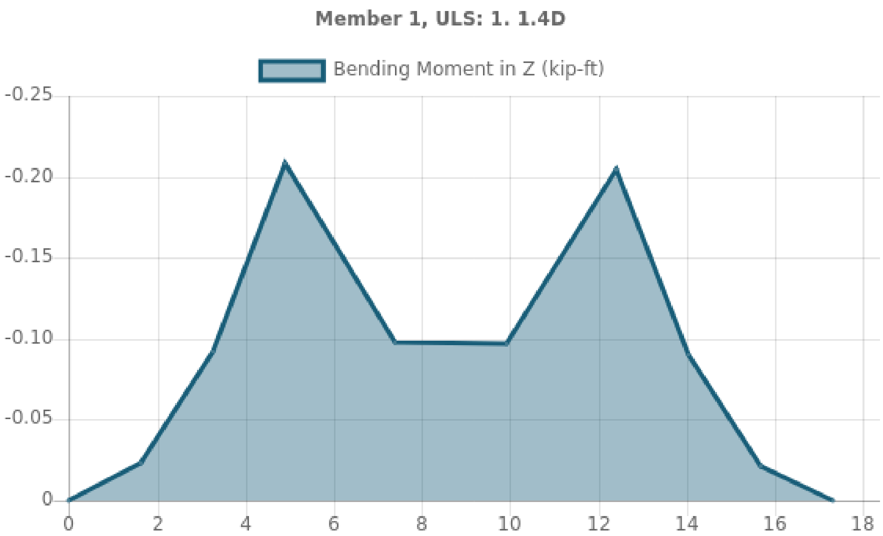

301
201
101
1
SkyCiv

## Rail Design Check

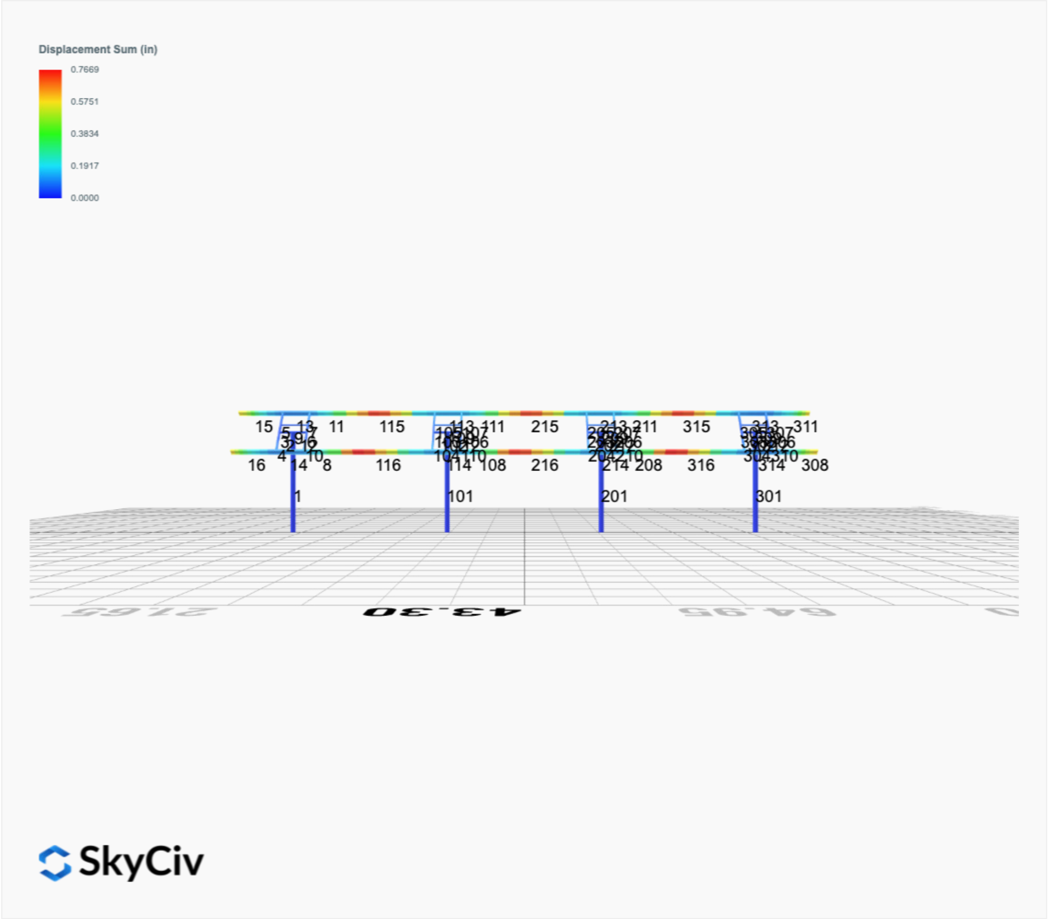
**Rail Length:** 17.3 ft
**Additional Restraints Required:** None
**Tributary Width:** 3.6083333333333333 ft
**Material:** Aluminium
**Density:** 169 lb/ft$^3$
**Elasticity Modulus:** 10000 ksi
**Fy:** 34.5 ksi
**Fu:** 37 ksi
**Snow (X):** 0.0434 kip/ft
**Snow (Y):** -0.0517 kip/ft
**Wind uplift Case A:** 0.0839 kip/ft
**Wind downforce Case A:** 0.0839 kip/ft
**Dead (Panel load) (X):** 0.0104 kip/ft
**Dead (Panel load) (Y):** -0.0124 kip/ft




| Result Check | Max Limit | Max Value | Utility | Status |
|---|---|---|---|---|
| Custom Stress Limit | 34.5 | 36.60735 | 1.061 | FAIL |
| Material Yield | 34.5 | 36.60735 | 1.061 | FAIL |
| Material Strength | 37 | 36.60735 | 0.989 | PASS |

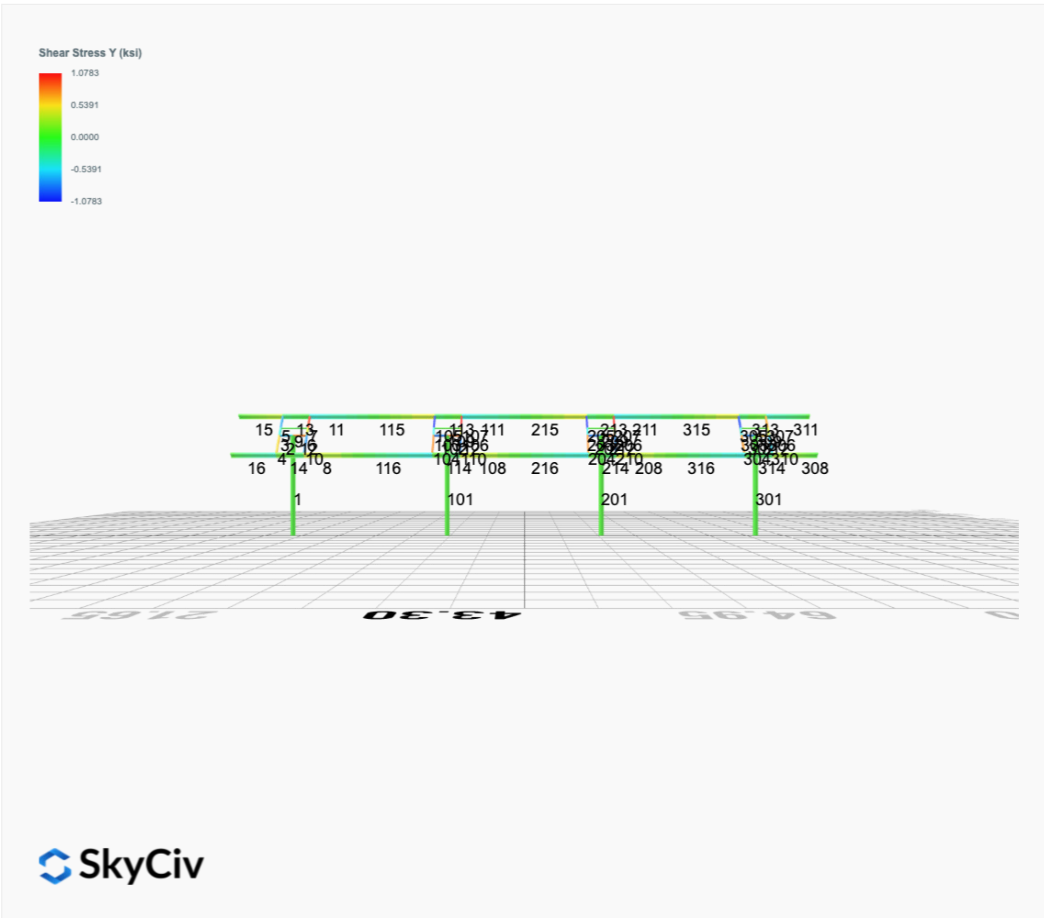


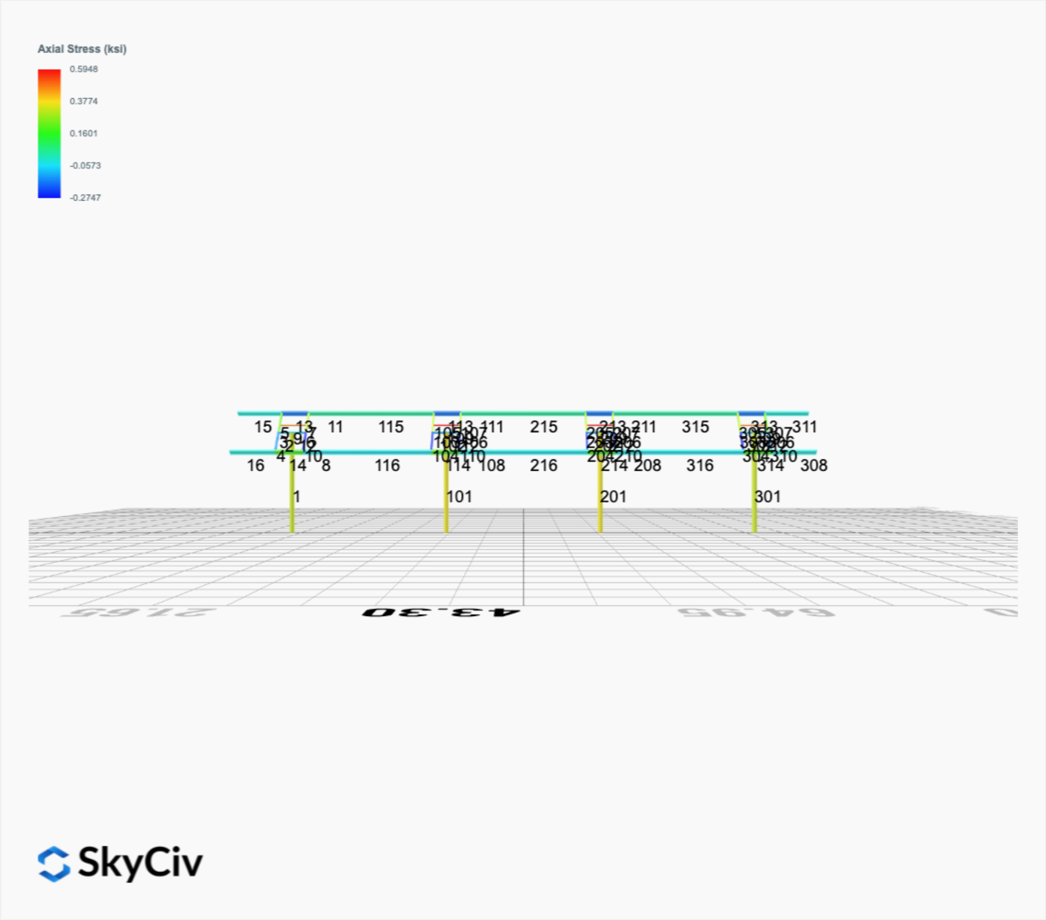
# FEM Results (Envelope Worst Case for each member)





Top Bending Stress Y (ksi)
23.9893
11.9310
-0.1272
-12.1854
-24.2437


Shear Stress Y (ksi)
1.0783
0.5391
0.0000
-0.5391
-1.0783


Axial Stress (ksi)
0.5948
0.3774
0.1601
-0.0573
-0.2747
1
101
201
301
43.30
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 | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 2. D + L | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 3. D + (S or Lr or R) | 0.0292 | 7.0281 | 0.0916 | 0.4272 | -0.0468 | -0.3678 |
| ULS: 3. D + (S or Lr or R) | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0243 | 6.0064 | 0.0763 | 0.3557 | -0.0389 | -0.3037 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 5b. D + 0.7E | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0243 | 6.0064 | 0.0763 | 0.3557 | -0.0389 | -0.3037 |
| ULS: 8. 0.6D + 0.7E | 0.0058 | 1.7648 | 0.0182 | 0.0846 | -0.0091 | -0.0669 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.7589 | 6.0770 | 0.1412 | 0.6291 | -0.6868 | 56.1823 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 3.7732 | -0.1916 | -0.0760 | -0.3255 | 0.6297 | -54.3777 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8021 | 8.3582 | 0.1595 | 0.7217 | -0.5427 | 41.9166 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0243 | 6.0064 | 0.0763 | 0.3557 | -0.0389 | -0.3037 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.8469 | 3.6568 | -0.0035 | 0.0058 | 0.4447 | -41.0034 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0243 | 6.0064 | 0.0763 | 0.3557 | -0.0389 | -0.3037 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8167 | 5.2931 | 0.1135 | 0.5071 | -0.5189 | 42.1089 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.8323 | 0.5916 | -0.0494 | -0.2089 | 0.4685 | -40.8112 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0097 | 2.9413 | 0.0303 | 0.1410 | -0.0151 | -0.1114 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.7627 | 4.9005 | 0.1291 | 0.5727 | -0.6808 | 56.2269 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0058 | 1.7648 | 0.0182 | 0.0846 | -0.0091 | -0.0669 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 3.7693 | -1.3681 | -0.0881 | -0.3819 | 0.6357 | -54.3331 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0058 | 1.7648 | 0.0182 | 0.0846 | -0.0091 | -0.0669 |

### 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 | 12.6836 |
| Shear X | -6.2980 |
| Shear Z | 0.2556 |
| Moment X | 1.1435 |
| Moment Y (Twist) | 1.1752 |
| Moment Z | 95.5562 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 8.3582 |
| Shear X | -3.7732 |
| Shear Z | 0.1595 |
| Moment X | 0.7217 |
| Moment Y (Twist) | 0.6868 |
| Moment Z | 56.2269 |

## 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 | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 2. D + L | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 3. D + (S or Lr or R) | -0.0292 | 7.9407 | 0.0000 | -0.0005 | -0.0018 | 0.4564 |
| ULS: 3. D + (S or Lr or R) | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0243 | 6.7667 | 0.0000 | -0.0004 | -0.0015 | 0.3822 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 5b. D + 0.7E | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0243 | 6.7667 | 0.0000 | -0.0004 | -0.0015 | 0.3822 |
| ULS: 8. 0.6D + 0.7E | -0.0058 | 1.9468 | -0.0000 | -0.0001 | -0.0003 | 0.0958 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.2466 | 6.8263 | 0.0311 | 0.1359 | -0.2080 | 63.2101 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.2323 | -0.3398 | -0.0284 | -0.1239 | 0.1899 | -60.5092 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.2020 | 9.4529 | 0.0233 | 0.1016 | -0.1571 | 47.6701 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0243 | 6.7667 | 0.0000 | -0.0004 | -0.0015 | 0.3822 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1572 | 4.0783 | -0.0212 | -0.0932 | 0.1414 | -45.1194 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0243 | 6.7667 | 0.0000 | -0.0004 | -0.0015 | 0.3822 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1873 | 5.9309 | 0.0233 | 0.1018 | -0.1561 | 47.4475 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1718 | 0.5563 | -0.0213 | -0.0930 | 0.1423 | -45.3420 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0097 | 3.2446 | -0.0000 | -0.0002 | -0.0005 | 0.1596 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.2427 | 5.5284 | 0.0311 | 0.1359 | -0.2078 | 63.1463 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0058 | 1.9468 | -0.0000 | -0.0001 | -0.0003 | 0.0958 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.2362 | -1.6377 | -0.0284 | -0.1238 | 0.1901 | -60.5731 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0058 | 1.9468 | -0.0000 | -0.0001 | -0.0003 | 0.0958 |

### 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 | 14.3901 |
| Shear X | -7.0780 |
| Shear Z | 0.0544 |
| Moment X | 0.2372 |
| Moment Y (Twist) | 0.3632 |
| Moment Z | 107.7597 |

### 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 | 9.4529 |
| Shear X | -4.2466 |
| Shear Z | 0.0311 |
| Moment X | 0.1359 |
| Moment Y (Twist) | 0.2080 |
| Moment Z | 63.2101 |

## 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 | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 2. D + L | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 3. D + (S or Lr or R) | -0.0292 | 7.9407 | -0.0000 | 0.0004 | 0.0020 | 0.4565 |
| ULS: 3. D + (S or Lr or R) | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0243 | 6.7667 | -0.0000 | 0.0003 | 0.0016 | 0.3823 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 5b. D + 0.7E | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0243 | 6.7667 | -0.0000 | 0.0003 | 0.0016 | 0.3823 |
| ULS: 8. 0.6D + 0.7E | -0.0058 | 1.9468 | 0.0000 | 0.0001 | 0.0003 | 0.0958 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.2466 | 6.8263 | -0.0311 | -0.1359 | 0.2080 | 63.2101 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 4.2323 | -0.3398 | 0.0284 | 0.1239 | -0.1899 | -60.5092 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |

| 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 | -3.2020 | 9.4529 | -0.0233 | -0.1017 | 0.1572 | 47.6701 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0243 | 6.7667 | -0.0000 | 0.0003 | 0.0016 | 0.3823 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1572 | 4.0783 | 0.0213 | 0.0931 | -0.1412 | -45.1194 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0243 | 6.7667 | -0.0000 | 0.0003 | 0.0016 | 0.3823 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.1873 | 5.9309 | -0.0233 | -0.1019 | 0.1561 | 47.4475 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 3.1718 | 0.5563 | 0.0213 | 0.0930 | -0.1423 | -45.3420 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0097 | 3.2446 | 0.0000 | 0.0002 | 0.0006 | 0.1596 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.2427 | 5.5284 | -0.0311 | -0.1360 | 0.2078 | 63.1463 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0058 | 1.9468 | 0.0000 | 0.0001 | 0.0003 | 0.0958 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 4.2362 | -1.6377 | 0.0284 | 0.1238 | -0.1901 | -60.5731 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0058 | 1.9468 | 0.0000 | 0.0001 | 0.0003 | 0.0958 |

### 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 | 14.3901 |
| Shear X | -7.0780 |
| Shear Z | -0.0544 |
| Moment X | -0.2382 |
| Moment Y (Twist) | 0.3637 |
| Moment Z | 107.7602 |

### 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 | 9.4529 |
| Shear X | -4.2466 |
| Shear Z | -0.0311 |
| Moment X | -0.1360 |
| Moment Y (Twist) | 0.2080 |
| Moment Z | 63.2101 |

## 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 | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 2. D + L | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 3. D + (S or Lr or R) | 0.0292 | 7.0281 | -0.0916 | -0.4276 | 0.0469 | -0.3677 |
| ULS: 3. D + (S or Lr or R) | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0243 | 6.0064 | -0.0763 | -0.3559 | 0.0390 | -0.3036 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 5b. D + 0.7E | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0243 | 6.0064 | -0.0763 | -0.3559 | 0.0390 | -0.3036 |
| ULS: 8. 0.6D + 0.7E | 0.0058 | 1.7648 | -0.0182 | -0.0847 | 0.0091 | -0.0669 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.7589 | 6.0770 | -0.1412 | -0.6291 | 0.6868 | 56.1823 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 3.7732 | -0.1916 | 0.0760 | 0.3255 | -0.6296 | -54.3777 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8021 | 8.3582 | -0.1595 | -0.7220 | 0.5428 | 41.9167 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0243 | 6.0064 | -0.0763 | -0.3559 | 0.0390 | -0.3036 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.8469 | 3.6567 | 0.0034 | -0.0060 | -0.4446 | -41.0033 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0243 | 6.0064 | -0.0763 | -0.3559 | 0.0390 | -0.3036 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.8167 | 5.2931 | -0.1135 | -0.5071 | 0.5189 | 42.1089 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.8323 | 0.5916 | 0.0494 | 0.2088 | -0.4684 | -40.8111 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0097 | 2.9413 | -0.0303 | -0.1411 | 0.0152 | -0.1114 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.7627 | 4.9005 | -0.1291 | -0.5727 | 0.6808 | 56.2269 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0058 | 1.7648 | -0.0182 | -0.0847 | 0.0091 | -0.0669 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 3.7693 | -1.3681 | 0.0881 | 0.3819 | -0.6357 | -54.3331 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0058 | 1.7648 | -0.0182 | -0.0847 | 0.0091 | -0.0669 |

### 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 | 12.6835 |
| Shear X | -6.2979 |
| Shear Z | -0.2556 |
| Moment X | -1.1445 |
| Moment Y (Twist) | 1.1756 |
| Moment Z | 95.5579 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 8.3582 |
| Shear X | -3.7732 |
| Shear Z | -0.1595 |
| Moment X | -0.7220 |
| Moment Y (Twist) | 0.6868 |
| Moment Z | 56.2269 |

## Project Details

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

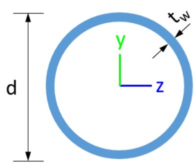
User Name: sales@mtsolar.us
Project Name: Winthrop 4x12-50D-8ft
Unit System: imperial

## Design Input Information

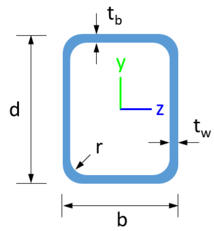
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

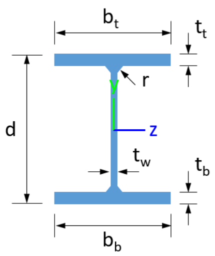
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 2in Pipe Sch 120 | 2.38 | 0.25 | | | | | |
| 6 | 4in Pipe Sch 120 | 4.50 | 0.44 | | | | | |
| 10 | 8in Pipe Sch 80 | 8.63 | 0.50 | | | | | |




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




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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 2in Pipe Sch 120 | 1.67 | 1.91 | 0.96 | 0.96 | 0.00 | 1.13 | 1.13 |
| 6 | 4in Pipe Sch 120 | 5.58 | 23.29 | 11.64 | 11.64 | 0.00 | 7.24 | 7.24 |
| 10 | 8in Pipe Sch 80 | 12.76 | 211.43 | 105.72 | 105.72 | 0.00 | 33.05 | 33.05 |
| 17 | HSS5x3x1/4 | 3.37 | 11.00 | 4.81 | 10.70 | 0.93 | 3.77 | 5.38 |
| 20 | W10x12 | 3.54 | 0.05 | 2.18 | 53.80 | 50.90 | 1.74 | 12.60 |

**Member Properties**

| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 30.72 | 30.72 | 14.63 | - | 300 | 200 | 1 |
| 2 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19 | 300 | 200 | 1 |
| 4 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 5 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 6 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 7 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 8 | 20 | 1.33 | 1.33 | 2.05 | 2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09 | 300 | 200 | 1 |
| 9 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 11 | 20 | 1.33 | 1.33 | 2.05 | 2.10,2.10,2.10,2.10,2.10,2.10,2.14,2.10,2.35,2.10,2.14,2.10,2.19,2.10,2.12,2.10,1.66,2.10,2.14,2.10,2.35,2.10,2.14,2.10,2.15,2.10 | 300 | 200 | 1 |
| 12 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.05,1.08,1.06,1.08,1.06,1.08,1.07,1.08,1.14,1.08,1.07,1.08,1.05,1.08,1.06,1.08,1.06,1.08 | 300 | 200 | 1 |
| 14 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08,1.08,1.08,1.11,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08 | 300 | 200 | 1 |
| 15 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 101 | 10 | 30.72 | 30.72 | 14.63 | - | 300 | 200 | 1 |
| 102 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 104 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 105 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 106 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 107 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 108 | 20 | 1.33 | 1.33 | 2.05 | 2.27,2.27,2.27,2.27,2.27,2.27,2.33,2.27,2.15,2.27,2.34,2.27,2.33,2.27,2.30,2.27,1.84,2.27,2.33,2.27,2.14,2.27,2.34,2.27,2.37,2.27 | 300 | 200 | 1 |
| 109 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 111 | 20 | 1.33 | 1.33 | 2.05 | 2.29,2.29,2.29,2.29,2.29,2.29,2.11,2.29,1.84,2.29,2.10,2.29,2.07,2.29,2.15,2.29,1.46,2.29,2.11,2.29,1.80,2.29,2.10,2.29,2.08,2.29 | 300 | 200 | 1 |
| 112 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 113 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.05,1.03,1.04,1.03,1.03,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.05,1.03 | 300 | 200 | 1 |
| 114 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.05,1.03 | 300 | 200 | 1 |
| 115 | 20 | 8.42 | 8.42 | 12.95 | 1.16,1.16,1.16,1.16,1.16,1.16,1.13,1.16,1.12,1.16,1.12,1.16,1.12,1.16,1.14,1.16,1.32,1.16,1.13,1.16,1.12,1.16,1.12,1.16,1.12,1.16 | 300 | 200 | 1 |
| 116 | 20 | 8.42 | 8.42 | 12.95 | 1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.14,1.17,1.15,1.17,1.15,1.17,1.16,1.17,1.21,1.17,1.16,1.17,1.14,1.17,1.15,1.17,1.15,1.17 | 300 | 200 | 1 |
| 201 | 10 | 30.72 | 30.72 | 14.63 | - | 300 | 200 | 1 |
| 202 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 204 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.69,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 205 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 206 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 207 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 208 | 20 | 1.33 | 1.33 | 2.05 | 2.32,2.32,2.32,2.32,2.32,2.32,2.19,2.32,2.12,2.32,2.15,2.32,2.13,2.32,2.36,2.32,2.03,2.32,2.21,2.32,2.12,2.32,2.15,2.32,2.14,2.32 | 300 | 200 | 1 |
| 209 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 211 | 20 | 1.33 | 1.33 | 2.05 | 2.35,2.35,2.35,2.35,2.35,2.35,2.08,2.35,1.63,2.35,2.04,2.35,1.79,2.35,2.11,2.35,1.54,2.35,2.08,2.35,1.59,2.35,2.01,2.35,1.84,2.35 | 300 | 200 | 1 |
| 212 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.06,1.03,1.04,1.03,1.03,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.05,1.03 | 300 | 200 | 1 |
| 214 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.03,1.03,1.04,1.03,1.05,1.03,1.04,1.03,1.05,1.03 | 300 | 200 | 1 |
| 215 | 20 | 8.42 | 8.42 | 12.95 | 1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.17,1.12,1.17,1.14,1.17,1.13,1.17,1.15,1.17,2.07,1.17,1.14,1.17,1.12,1.17,1.14,1.17,1.13,1.17 | 300 | 200 | 1 |
| 216 | 20 | 8.42 | 8.42 | 12.95 | 1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.22,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.16,1.17 | 300 | 200 | 1 |
| 301 | 10 | 30.72 | 30.72 | 14.63 | - | 300 | 200 | 1 |
| 302 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 303 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 304 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 305 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 306 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.19,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19 | 300 | 200 | 1 |
| 307 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 308 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 309 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 310 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.69,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 311 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 312 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 313 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.06,1.08,1.05,1.08,1.06,1.08,1.06,1.08,1.07,1.08,1.14,1.08,1.07,1.08,1.05,1.08,1.06,1.08,1.06,1.08 | 300 | 200 | 1 |
| 314 | 20 | 4.88 | 4.00 | 7.5 | 1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.06,1.08,1.07,1.08,1.07,1.08,1.08,1.08,1.11,1.08,1.07,1.08,1.0 | 30 | 20 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 314 | 20 | 4.88 | 4.00 | 0 | 6,1.08,1.07,1.08,1.07,1.08 | 0 | 0 | 1 |
| 315 | 20 | 8.42 | 8.42 | 12.95 | 1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.14,1.16,1.14,1.15,1.14,1.16,1.14,1.15,1.14,1.15,1.14,1.15,1.14,1.17,1.14,1.15,1.14,1.16,1.14 | 300 | 200 | 1 |
| 316 | 20 | 8.42 | 8.42 | 12.95 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.15,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13 | 300 | 200 | 1 |

## Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|---|---|---|---|---|---|---|
| 1 | 574.32 | 175.80 | 123.94 | 123.94 | 172.30 | 172.30 |
| 2 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 3 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 4 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 5 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 6 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 7 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 8 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 9 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 10 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 11 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 12 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 13 | 159.30 | 97.43 | 32.09 | 6.46 | 56.26 | 44.91 |
| 14 | 159.30 | 97.43 | 32.45 | 6.46 | 56.26 | 44.91 |
| 15 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 16 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 101 | 574.32 | 175.80 | 123.94 | 123.94 | 172.30 | 172.30 |
| 102 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 103 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 104 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 105 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 106 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 107 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 108 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 109 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 110 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 111 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 112 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 113 | 159.30 | 97.43 | 31.38 | 6.46 | 56.26 | 44.91 |
| 114 | 159.30 | 97.43 | 31.54 | 6.46 | 56.26 | 44.91 |
| 115 | 159.30 | 48.27 | 14.83 | 6.46 | 56.26 | 44.91 |
| 116 | 159.30 | 48.27 | 15.20 | 6.46 | 56.26 | 44.91 |
| 201 | 574.32 | 175.80 | 123.94 | 123.94 | 172.30 | 172.30 |
| 202 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 203 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 204 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 205 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 206 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 207 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 208 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 209 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 210 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 211 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 212 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 213 | 159.30 | 97.43 | 31.39 | 6.46 | 56.26 | 44.91 |
| 214 | 159.30 | 97.43 | 31.54 | 6.46 | 56.26 | 44.91 |
| 215 | 159.30 | 48.27 | 14.90 | 6.46 | 56.26 | 44.91 |
| 216 | 159.30 | 48.27 | 15.27 | 6.46 | 56.26 | 44.91 |
| 301 | 574.32 | 175.80 | 123.94 | 123.94 | 172.30 | 172.30 |
| 302 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 303 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 304 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 305 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 306 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 307 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 308 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 309 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 310 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 311 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 312 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 313 | 159.30 | 97.43 | 32.08 | 6.46 | 56.26 | 44.91 |
| 314 | 159.30 | 97.43 | 32.47 | 6.46 | 56.26 | 44.91 |
| 315 | 159.30 | 48.27 | 15.09 | 6.46 | 56.26 | 44.91 |
| 316 | 159.30 | 48.27 | 15.04 | 6.46 | 56.26 | 44.91 |

## 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 | 0.072 | 0.771 | 0.021 | 0.037 | 0.001 | 0.811 | #13 | 0.640 | Not Required | Pass |
| 2 | 0.006 | 0.284 | 0.206 | 0.070 | 0.039 | 0.455 | #13 | 0.036 | Not Required | Pass |
| 3 | 0.010 | 0.478 | 0.060 | 0.047 | 0.009 | 0.501 | #13 | 0.046 | Not Required | Pass |
| 4 | 0.010 | 0.478 | 0.213 | 0.047 | 0.046 | 0.572 | #21 | 0.082 | Not Required | Pass |
| 5 | 0.010 | 0.296 | 0.213 | 0.047 | 0.056 | 0.327 | #21 | 0.076 | Not Required | Pass |
| 6 | 0.013 | 0.577 | 0.083 | 0.058 | 0.009 | 0.625 | #13 | 0.046 | Not Required | Pass |
| 7 | 0.014 | 0.358 | 0.287 | 0.057 | 0.074 | 0.394 | #13 | 0.076 | Not Required | Pass |
| 8 | 0.003 | 0.050 | 0.355 | 0.037 | 0.029 | 0.361 | #23 | 0.102 | Not Required | Pass |
| 9 | 0.028 | 0.042 | 0.070 | 0.003 | 0.002 | 0.111 | #13 | 0.206 | Not Required | Pass |
| 10 | 0.014 | 0.555 | 0.276 | 0.055 | 0.059 | 0.655 | #21 | 0.082 | Not Required | Pass |
| 11 | 0.004 | 0.043 | 0.365 | 0.038 | 0.029 | 0.378 | #21 | 0.102 | Not Required | Pass |
| 12 | 0.006 | 0.369 | 0.250 | 0.088 | 0.047 | 0.593 | #13 | 0.036 | Not Required | Pass |
| 13 | 0.010 | 0.206 | 0.766 | 0.047 | 0.036 | 0.901 | #21 | 0.306 | Not Required | Pass |
| 14 | 0.014 | 0.199 | 0.753 | 0.045 | 0.036 | 0.873 | #21 | 0.204 | Not Required | Pass |
| 15 | 0.000 | 0.067 | 0.306 | 0.024 | 0.019 | 0.366 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.067 | 0.306 | 0.024 | 0.019 | 0.366 | #21 | Not Required | Not Required | Pass |
| 101 | 0.082 | 0.869 | 0.004 | 0.041 | 0.000 | 0.906 | #13 | 0.640 | Not Required | Pass |
| 102 | 0.007 | 0.368 | 0.251 | 0.090 | 0.046 | 0.577 | #13 | 0.036 | Not Required | Pass |
| 103 | 0.013 | 0.578 | 0.067 | 0.057 | 0.001 | 0.617 | #13 | 0.046 | Not Required | Pass |
| 104 | 0.013 | 0.590 | 0.279 | 0.058 | 0.059 | 0.711 | #21 | 0.082 | Not Required | Pass |
| 105 | 0.013 | 0.359 | 0.290 | 0.057 | 0.076 | 0.406 | #21 | 0.076 | Not Required | Pass |
| 106 | 0.013 | 0.606 | 0.068 | 0.060 | 0.003 | 0.642 | #13 | 0.046 | Not Required | Pass |
| 107 | 0.013 | 0.376 | 0.284 | 0.059 | 0.074 | 0.416 | #13 | 0.076 | Not Required | Pass |
| 108 | 0.003 | 0.046 | 0.349 | 0.037 | 0.029 | 0.393 | #21 | 0.102 | Not Required | Pass |
| 109 | 0.033 | 0.040 | 0.054 | 0.001 | 0.000 | 0.102 | #13 | 0.206 | Not Required | Pass |
| 110 | 0.013 | 0.604 | 0.271 | 0.060 | 0.057 | 0.711 | #21 | 0.082 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 0.013 | 0.604 | 0.271 | 0.060 | 0.057 | 0.711 | #21 | 0.082 | Not Required | Pass |
| 111 | 0.004 | 0.047 | 0.358 | 0.037 | 0.029 | 0.395 | #21 | 0.102 | Not Required | Pass |
| 112 | 0.007 | 0.378 | 0.264 | 0.091 | 0.048 | 0.610 | #13 | 0.036 | Not Required | Pass |
| 113 | 0.011 | 0.190 | 0.771 | 0.046 | 0.036 | 0.932 | #21 | 0.306 | Not Required | Pass |
| 114 | 0.015 | 0.219 | 0.762 | 0.047 | 0.036 | 0.939 | #21 | 0.306 | Not Required | Pass |
| 115 | 0.011 | 0.423 | 0.409 | 0.036 | 0.029 | 0.781 | #21 | 0.644 | Not Required | Pass |
| 116 | 0.003 | 0.406 | 0.405 | 0.038 | 0.029 | 0.763 | #21 | 0.644 | Not Required | Pass |
| 201 | 0.082 | 0.869 | 0.004 | 0.041 | 0.000 | 0.906 | #13 | 0.640 | Not Required | Pass |
| 202 | 0.007 | 0.378 | 0.264 | 0.091 | 0.048 | 0.610 | #13 | 0.036 | Not Required | Pass |
| 203 | 0.013 | 0.606 | 0.068 | 0.060 | 0.003 | 0.642 | #13 | 0.046 | Not Required | Pass |
| 204 | 0.013 | 0.604 | 0.271 | 0.060 | 0.057 | 0.711 | #21 | 0.082 | Not Required | Pass |
| 205 | 0.013 | 0.376 | 0.284 | 0.059 | 0.074 | 0.416 | #13 | 0.076 | Not Required | Pass |
| 206 | 0.013 | 0.578 | 0.067 | 0.057 | 0.001 | 0.617 | #13 | 0.046 | Not Required | Pass |
| 207 | 0.013 | 0.359 | 0.290 | 0.057 | 0.076 | 0.406 | #21 | 0.076 | Not Required | Pass |
| 208 | 0.003 | 0.041 | 0.362 | 0.038 | 0.029 | 0.402 | #21 | 0.102 | Not Required | Pass |
| 209 | 0.033 | 0.040 | 0.054 | 0.001 | 0.000 | 0.102 | #13 | 0.206 | Not Required | Pass |
| 210 | 0.013 | 0.590 | 0.279 | 0.058 | 0.059 | 0.711 | #21 | 0.082 | Not Required | Pass |
| 211 | 0.004 | 0.054 | 0.371 | 0.036 | 0.029 | 0.401 | #21 | 0.102 | Not Required | Pass |
| 212 | 0.007 | 0.368 | 0.251 | 0.090 | 0.046 | 0.577 | #13 | 0.036 | Not Required | Pass |
| 213 | 0.011 | 0.190 | 0.772 | 0.046 | 0.036 | 0.932 | #21 | 0.306 | Not Required | Pass |
| 214 | 0.015 | 0.219 | 0.762 | 0.047 | 0.036 | 0.939 | #21 | 0.306 | Not Required | Pass |
| 215 | 0.011 | 0.417 | 0.409 | 0.037 | 0.029 | 0.760 | #21 | 0.644 | Not Required | Pass |
| 216 | 0.006 | 0.368 | 0.405 | 0.037 | 0.029 | 0.725 | #21 | 0.644 | Not Required | Pass |
| 301 | 0.072 | 0.771 | 0.021 | 0.037 | 0.001 | 0.811 | #13 | 0.640 | Not Required | Pass |
| 302 | 0.006 | 0.369 | 0.250 | 0.088 | 0.047 | 0.593 | #13 | 0.036 | Not Required | Pass |
| 303 | 0.013 | 0.577 | 0.083 | 0.058 | 0.009 | 0.625 | #13 | 0.046 | Not Required | Pass |
| 304 | 0.014 | 0.555 | 0.276 | 0.055 | 0.059 | 0.655 | #21 | 0.082 | Not Required | Pass |
| 305 | 0.014 | 0.358 | 0.287 | 0.057 | 0.074 | 0.394 | #13 | 0.076 | Not Required | Pass |
| 306 | 0.010 | 0.478 | 0.060 | 0.047 | 0.009 | 0.501 | #13 | 0.046 | Not Required | Pass |
| 307 | 0.010 | 0.296 | 0.213 | 0.047 | 0.056 | 0.327 | #21 | 0.076 | Not Required | Pass |
| 308 | 0.000 | 0.067 | 0.306 | 0.024 | 0.019 | 0.366 | #21 | Not Required | Not Required | Pass |
| 309 | 0.028 | 0.042 | 0.070 | 0.003 | 0.002 | 0.111 | #13 | 0.206 | Not Required | Pass |
| 310 | 0.010 | 0.478 | 0.213 | 0.047 | 0.046 | 0.572 | #21 | 0.082 | Not Required | Pass |
| 311 | 0.000 | 0.067 | 0.306 | 0.024 | 0.019 | 0.366 | #21 | Not Required | Not Required | Pass |
| 312 | 0.006 | 0.284 | 0.206 | 0.070 | 0.039 | 0.455 | #13 | 0.036 | Not Required | Pass |
| 313 | 0.010 | 0.207 | 0.765 | 0.047 | 0.036 | 0.900 | #21 | 0.204 | Not Required | Pass |
| 314 | 0.014 | 0.199 | 0.753 | 0.045 | 0.036 | 0.874 | #21 | 0.306 | Not Required | Pass |
| 315 | 0.011 | 0.418 | 0.409 | 0.038 | 0.029 | 0.778 | #21 | 0.644 | Not Required | Pass |
| 316 | 0.003 | 0.410 | 0.403 | 0.037 | 0.029 | 0.766 | #21 | 0.644 | 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 |
|---|---|---|

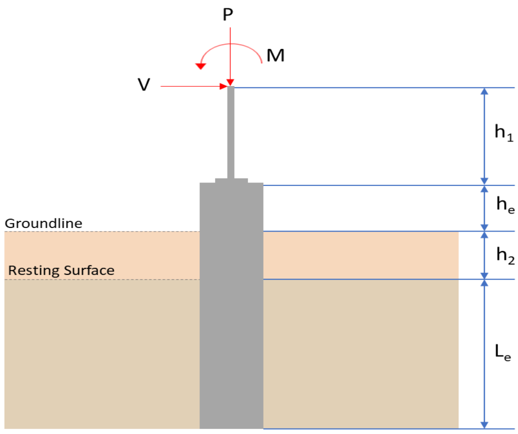
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.25$ ft - Total pile length

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

$h_2 = 0$ ft - Depth to resisting surface

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

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 8.358 | 12.684 |
| $V_x$ (kip) | -3.773 | -6.298 |
| $V_z$ (kip) | 0.159 | 0.256 |
| $M_x$ (kipft) | 0.722 | 1.143 |
| $M_z$ (kipft) | 56.227 | 95.556 |

**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,

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

$$H_o = \frac{(-3.773 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.6008 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(56.227\ \text{kipft}) + ((-3.773\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.9533\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6159\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.159\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.025318\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.722\ \text{kipft}) + ((0.159\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.11497\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.3359\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.6159\ \text{ft}), (2.3359\ \text{ft})]$$

$$L_{e,req} = 7.616\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.616\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.92315$$

Status: **PASS**
Ratio: **0.920**

**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

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

$$q = \frac{(8.358 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.52238 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.52238 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.26119$$

Status: **PASS**
Ratio: **0.260**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.6008 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9533 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9533 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.6008 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (8.9533 \text{ kipft/ft})) + (4 \times (-0.6008 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.6853 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9533 \text{ kipft/ft})) + (3 \times (-0.6008 \text{ kip/ft}) \times (8.25 \text{ ft}))]^{\,2}}{(8.25 \text{ ft})^2 \times [(3 \times (8.9533 \text{ kipft/ft})) + (2 \times (-0.6008 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.28521 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (8.9533 \text{ kipft/ft})) + ((-0.6008 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 1.1416 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.6853 \text{ ft})}{2}$$

$$p_a = 0.4264 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.28521 \text{ kip/ft}^2\right)}{\left(0.4264 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.66889$$

Status: **PASS**
Ratio: **0.670**

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

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$

$$p_s = 1.2375 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1416 \text{ kip/ft}^2\right)}{\left(1.2375 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.92251$$

Status: **PASS**
Ratio: **0.920**

**Considering z-direction:**

$H_o = 0.025318 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11497 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11497 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (0.025318 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.11497 \text{ kipft/ft})) + (4 \times (0.025318 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.8766 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11497 \text{ kipft/ft})) + (3 \times (0.025318 \text{ kip/ft}) \times (8.25 \text{ ft}))]^{\;2}}{(8.25 \text{ ft})^2 \times [(3 \times (0.11497 \text{ kipft/ft})) + (2 \times (0.025318 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.017056 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.11497 \text{ kipft/ft})) + ((0.025318 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 0.038683 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8766 \text{ ft})}{2}$$

$$p_a = 0.44074 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.017056 \text{ kip/ft}^2\right)}{\left(0.44074 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.038699$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

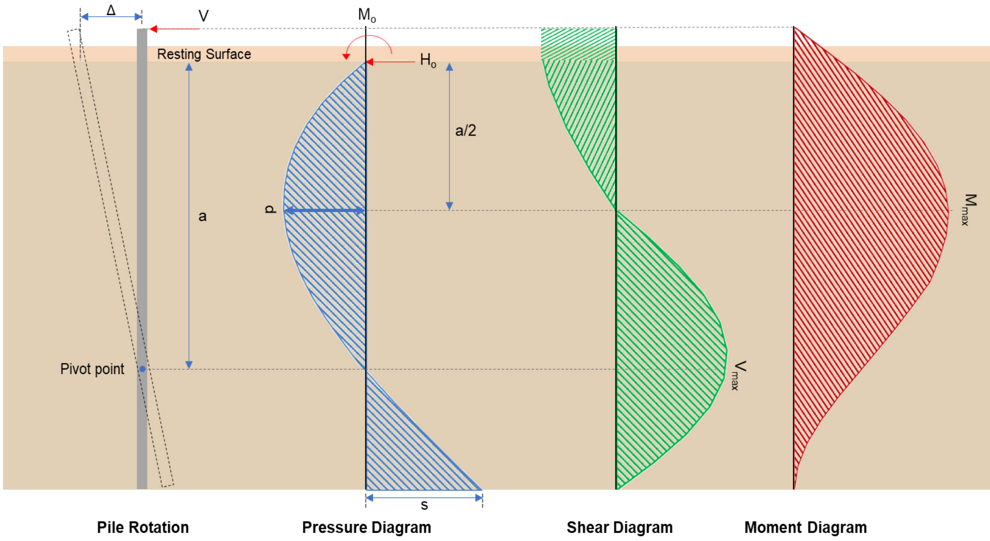
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.038683\ \mathrm{kip/ft^2})}{(1.2375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.031259$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-6.298\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0029\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(95.556\ \mathrm{kipft}) + ((-6.298\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.216\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(15.216\ \mathrm{kipft/ft})}{(-1.0029\ \mathrm{kip/ft})}$$

$$E = 15.172\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (15.216\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.0029\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (15.216\ \text{kipft/ft})) + (4 \times (-1.0029\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6829\ \text{ft}$$

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

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

$$V_{max} = ((-1.0029\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.172\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6829\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.172\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6829\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.701\ \text{kip}$$

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

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

$$M_{max} = ((-1.0029\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(15.172\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (15.172\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.172\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.76\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.256\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.040764\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.143\ \text{kipft}) + ((0.256\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.18201\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.18201\ \text{kipft/ft})}{(0.040764\ \text{kip/ft})}$$

$$E = 4.4648\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.18201\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.040764\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.18201\ \text{kipft/ft})) + (4 \times (0.040764\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.8795\ \text{ft}$$

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

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

$$V_{max} = ((0.040764\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.4648\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8795\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.4648\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8795\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.26466\ \text{kip}$$

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

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

$$M_{max} = ((0.040764\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(4.4648\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.8795\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.4648\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8795\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.4648\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8795\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.97161\ \text{kipft}$$

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.684\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.175\ \text{in}^2$$

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

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

$$A_{min} = Max\left[(-84.175\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

$n_{rebar}$ - 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

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

$$Ratio = \frac{(12.684\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0047414$$

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 $f'_{ck} = 2.5 \text{ ksi} \to 2500 \text{ psi}$, $P = 12.684 \text{ kip} \to 12684 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12684 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.18 \text{ kip}$$

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

*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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.18 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.18 \text{ kip}$$

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

*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

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

$$\phi V_n = (0.65) \times ((120.18 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.2 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 15.701 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{(15.701\ \text{kip})}{(111.2\ \text{kip})}$$ $$Ratio = 0.1412$$ | Status: **PASS** Ratio: **0.140** |
| | **Considering z-direction:** <br> $V_{max} = 0.26466\ \text{kip}$ - Maximum shear force in the z-direction, <br> $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.26466\ \text{kip})}{(111.2\ \text{kip})}$$ $$Ratio = 0.0023801$$ | Status: **PASS** 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> $M_{max} = 61.76\ \text{kipft}$ - Maximum moment in the x-direction, <br> $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(61.76\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.24743$$ | Status: **PASS** Ratio: **0.250** |
| | **Considering z-direction:** <br> $M_{max} = 0.97161\ \text{kipft}$ - Maximum moment in the z-direction, <br> $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | |
|---|---|---|
| | $$Ratio = \frac{(0.97161 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0038927$$ | Status: **PASS**<br>Ratio: **0.000** |

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

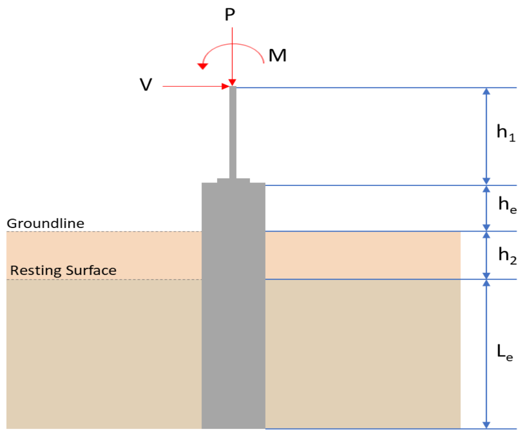
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 8.25\ \text{ft}$ - 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 $(q_a)$ $(\text{psf})$ | Allowable Lateral Pressure $(R)$ $(\text{psf/ft})$ |
|---|---|---|---|
| 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 |

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 8.358 | 12.683 |
| $V_x$ (kip) | -3.773 | -6.298 |
| $V_z$ (kip) | -0.159 | -0.256 |
| $M_x$ (kipft) | -0.722 | -1.144 |
| $M_z$ (kipft) | 56.227 | 95.558 |

**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,

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

$$H_o = \frac{(-3.773\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.6008\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(56.227\ \text{kipft}) + ((-3.773\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.9533\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6159\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.159\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.025318\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.722\ \text{kipft}) + ((-0.159\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.11497\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.8547\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.6159\ \text{ft}), (1.8547\ \text{ft})]$$

$$L_{e,req} = 7.616\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.616\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.92315$$

Status: **PASS**
Ratio: **0.920**

**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

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

$$q = \frac{(8.358\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.52238\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.52238\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.26119$$

Status: **PASS**
Ratio: **0.260**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.6008\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9533\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9533\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.6008\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (8.9533\ \mathrm{kipft/ft})) + (4 \times (-0.6008\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6853\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9533\ \mathrm{kipft/ft})) + (3 \times (-0.6008\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (8.9533\ \mathrm{kipft/ft})) + (2 \times (-0.6008\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.28521\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (8.9533\ \mathrm{kipft/ft})) + ((-0.6008\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1416\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6853\ \mathrm{ft})}{2}$$

$$p_a = 0.4264\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.28521\ \mathrm{kip/ft^2}\right)}{\left(0.4264\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.66889$$ $p_s$ - Allowable lateral soil pressure at depth $L_e$, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$ $$p_s = 1.2375\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1416\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.92251$$ | Status: **PASS**<br>Ratio: **0.670**<br><br>Status: **PASS**<br>Ratio: **0.920** | |
| | **Considering z-direction:**<br>$H_o = -0.025318\ \mathrm{kip/ft}$ - Lateral force per length of pile,<br>$M_o = 0.11497\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,<br>$a$ - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.11497\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.025318\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.11497\ \mathrm{kipft/ft})) + (4 \times (-0.025318\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$ $$a = 5.8766\ \mathrm{ft}$$ $p$ - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.11497\ \mathrm{kipft/ft})) + (3 \times (-0.025318\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.11497\ \mathrm{kipft/ft})) + (2 \times (-0.025318\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$ $$p = -0.0042063\ \mathrm{kip/ft^2}$$ $s$ - Earth pressure against the pile at distance $L_e$, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.11497\ \mathrm{kipft/ft})) + ((-0.025318\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$ $$s = 0.0018564\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:**<br>$p_a$ - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8766\ \mathrm{ft})}{2}$$ $$p_a = 0.44074\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.0042063\ \mathrm{kip/ft^2}\right)}{\left(0.44074\ \mathrm{kip/ft^2}\right)}$$ | | |

$$Ratio = -0.0095437$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

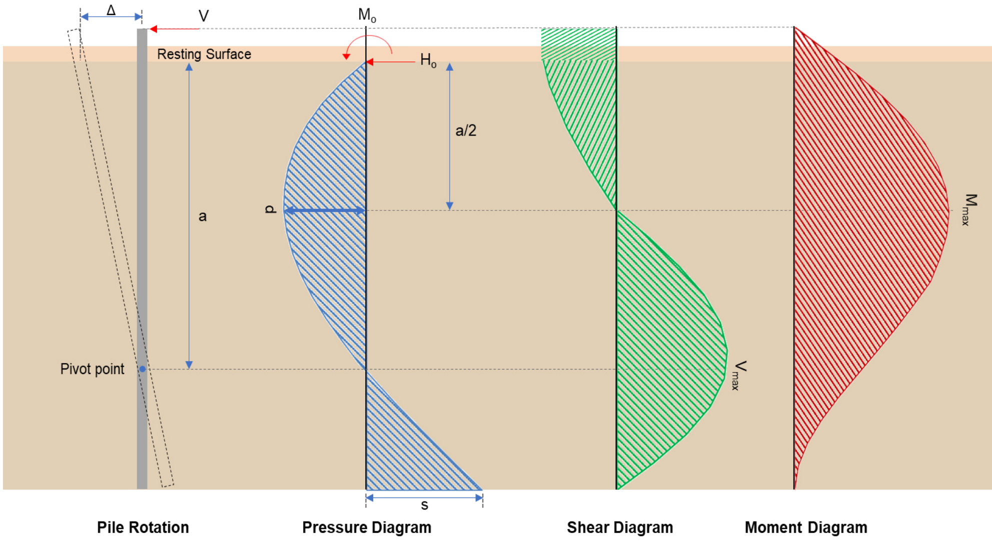
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0018564\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0015001$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-6.298\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0029\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(95.558\ \mathrm{kipft}) + ((-6.298\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.216\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(15.216\ \mathrm{kipft/ft})}{(-1.0029\ \mathrm{kip/ft})}$$

$$E = 15.173\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (15.216\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.0029\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{\qquad}{(6 \times (15.216\ \text{kipft/ft})) + (4 \times (-1.0029\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6829\ \text{ft}$$

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

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

$$V_{max} = ((-1.0029\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.173\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6829\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.173\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6829\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.701\ \text{kip}$$

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

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

$$M_{max} = ((-1.0029\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(15.173\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (15.173\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.173\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6829\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.761\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.256\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.040764\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.144\ \text{kipft}) + ((-0.256\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.18217\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.18217\ \text{kipft/ft})}{(-0.040764\ \text{kip/ft})}$$

$$E = 4.4687\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.18217\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.040764\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.18217\ \text{kipft/ft})) + (4 \times (-0.040764\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.8793\ \text{ft}$$

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

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

$$V_{max} = ((-0.040764\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.4687\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8793\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.4687\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8793\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.2648\ \text{kip}$$

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

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

$$M_{max} = ((-0.040764\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(4.4687\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.8793\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.4687\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.8793\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.4687\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.8793\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.97217\ \text{kipft}$$

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.683\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.175\ \text{in}^2$$

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

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

$$A_{min} = Max\left[(-84.175\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

$n_{rebar}$ - 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

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

$$Ratio = \frac{(12.683\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.004741$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ , $P = 12.683 \text{ kip} \rightarrow 12683 \text{ lbf}$ ,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12683 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.18 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.18 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.18 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.18 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.2 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 15.701 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $$Ratio = \frac{(15.701\ \mathrm{kip})}{(111.2\ \mathrm{kip})}$$ $$Ratio = 0.1412$$ | Status: **PASS**<br>Ratio: **0.140** |
| | **Considering z-direction:**<br>$V_{max} = 0.2648\ \mathrm{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.2648\ \mathrm{kip})}{(111.2\ \mathrm{kip})}$$ $$Ratio = 0.0023814$$ | 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>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ 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>$M_{max} = 61.761\ \mathrm{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(61.761\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.24744$$ | Status: **PASS**<br>Ratio: **0.250** |
| | **Considering z-direction:**<br>$M_{max} = 0.97217\ \mathrm{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{(0.97217\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0038949$$ | Status: **PASS**<br>Ratio: **0.000** |

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

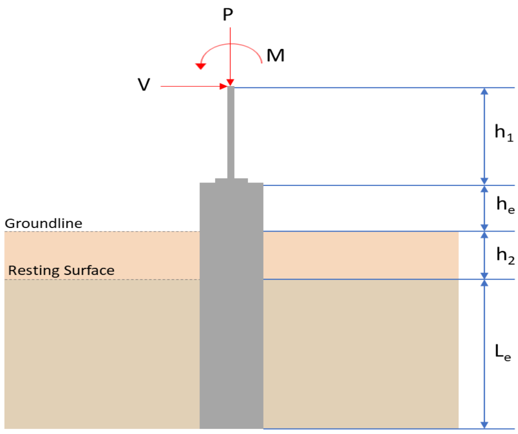
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular

$b = 48\ \text{in}$ - Pile width

$D = 48\ \text{in}$ - Pile depth

$L = 8.5\ \text{ft}$ - 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) | 9.453 | 14.390 |
| $V_x$ (kip) | -4.247 | -7.078 |
| $V_z$ (kip) | 0.031 | 0.054 |
| $M_x$ (kipft) | 0.136 | 0.237 |
| $M_z$ (kipft) | 63.210 | 107.760 |

**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,

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

$$H_o = \frac{(-4.247\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.67627\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(63.21\ \mathrm{kipft}) + ((-4.247\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.065\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.8631\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.031\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0049363\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.136\ \mathrm{kipft}) + ((0.031\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.021656\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.2832\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.8631\ \mathrm{ft}), (1.2832\ \mathrm{ft})]$$

$$L_{e,req} = 7.863\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.863\ \mathrm{ft})}{(8.5\ \mathrm{ft})}$$

$$Ratio = 0.92506$$

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

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

$$q = \frac{(9.453\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.59081\ \text{kip}/\text{ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.59081\ \text{kip}/\text{ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.29541$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2.125$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.67627\ \text{kip}/\text{ft}$ - Lateral force per length of pile,
$M_o = 10.065\ \text{kipft}/\text{ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.065\ \text{kipft}/\text{ft}) \times (8.5\ \text{ft})) + \left(3 \times (-0.67627\ \text{kip}/\text{ft}) \times (8.5\ \text{ft})^2\right)}{(6 \times (10.065\ \text{kipft}/\text{ft})) + (4 \times (-0.67627\ \text{kip}/\text{ft}) \times (8.5\ \text{ft}))}$$

$$a = 5.862\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.065\ \text{kipft}/\text{ft})) + (3 \times (-0.67627\ \text{kip}/\text{ft}) \times (8.5\ \text{ft}))]^2}{(8.5\ \text{ft})^2 \times [(3 \times (10.065\ \text{kipft}/\text{ft})) + (2 \times (-0.67627\ \text{kip}/\text{ft}) \times (8.5\ \text{ft}))]}$$

$$p = 0.29408\ \text{kip}/\text{ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (10.065\ \text{kipft}/\text{ft})) + ((-0.67627\ \text{kip}/\text{ft}) \times (8.5\ \text{ft}))]}{(8.5\ \text{ft})^2}$$

$$s = 1.1944\ \text{kip}/\text{ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf}/\text{ft}) \times \frac{(5.862\ \text{ft})}{2}$$

$$p_a = 0.43965\ \text{kip}/\text{ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29408\ \mathrm{kip/ft^2}\right)}{\left(0.43965\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.6689$$

Status: **PASS**
Ratio: **0.670**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1944\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93676$$

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

**Considering z-direction:**

$H_o = 0.0049363\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.021656\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.021656\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.021656\ \mathrm{kipft/ft})) + (4 \times (0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.0659\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.021656\ \mathrm{kipft/ft})) + (3 \times (0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.021656\ \mathrm{kipft/ft})) + (2 \times (0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.0031484\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.021656\ \mathrm{kipft/ft})) + ((0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0070813\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0659\ \mathrm{ft})}{2}$$

$$p_a = 0.45494\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0031484\ \mathrm{kip/ft^2}\right)}{\left(0.45494\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0069204$$

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

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

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8.5\ \text{ft})$$

$$p_s = 1.275\ \text{kip/ft}^2$$

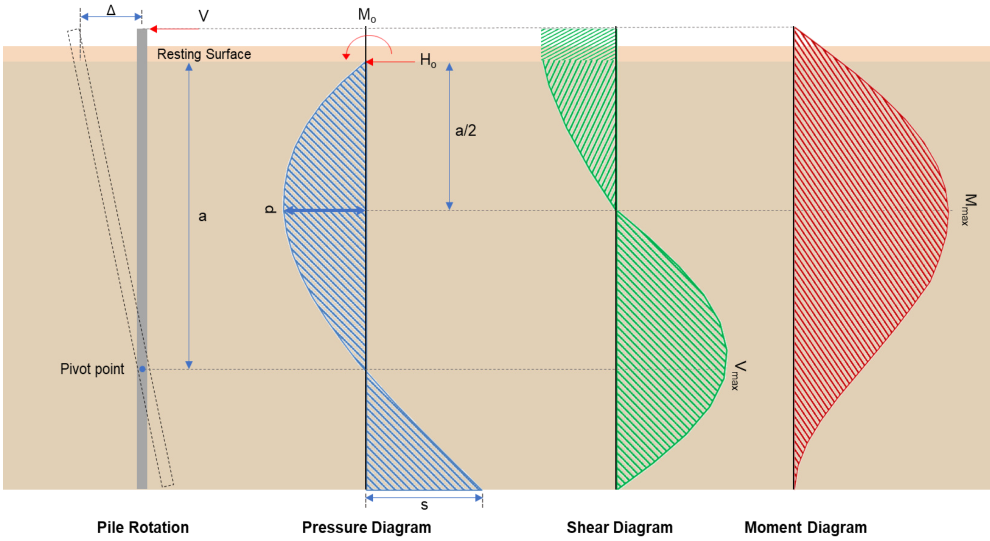
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0070813\ \text{kip/ft}^2\right)}{\left(1.275\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.005554$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-7.078\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.1271\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(107.76\ \text{kipft}) + ((-7.078\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 17.159\ \text{kipft/ft}$$

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

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

$$E = \frac{(17.159\ \text{kipft/ft})}{(-1.1271\ \text{kip/ft})}$$

$$E = 15.225\ \text{ft}$$

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

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

$$a = \frac{(4 \times (17.159\ \text{kipft/ft}) \times (8.5\ \text{ft})) + \left(3 \times (-1.1271\ \text{kip/ft}) \times (8.5\ \text{ft})^2\right)}{\cdots}$$

$$a = \frac{}{(6 \times (17.159 \text{ kipft/ft})) + (4 \times (-1.1271 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8588 \text{ ft}$$

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

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

$$V_{max} = ((-1.1271 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.225 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8588 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.225 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8588 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 17.263 \text{ kip}$$

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

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

$$M_{max} = ((-1.1271 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(15.225 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8588 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (15.225 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8588 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.225 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8588 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 69.886 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.054 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0085987 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.237 \text{ kipft}) + ((0.054 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.037739 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.037739 \text{ kipft/ft})}{(0.0085987 \text{ kip/ft})}$$

$$E = 4.3889 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.037739 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (0.0085987 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.037739 \text{ kipft/ft})) + (4 \times (0.0085987 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0658 \text{ ft}$$

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

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

$$V_{max} = ((0.0085987\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.3889\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.0658\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.3889\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.0658\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.054331\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0085987\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.5\ \mathrm{ft})) \times \left[\left(\frac{(4.3889\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + \frac{(6.0658\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (4.3889\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.0658\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.3889\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.0658\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.20482\ \mathrm{kipft}$$

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.39\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.118\ \mathrm{in}^2$$

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

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

$$A_{min} = Max\left[(-84.118\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

$n_{rebar}$ - 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 Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)

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

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

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

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

**Summary:**

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.39\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0053791$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ , $P = 14.39 \text{ kip} \rightarrow 14390 \text{ lbf}$ ,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14390 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.4 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.4 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.4 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.4 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.34 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 17.263 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.263 \text{ kip})}{(111.34 \text{ kip})}$$

$$Ratio = 0.15504$$

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

**Considering z-direction:**

$V_{max} = 0.054331 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.054331 \text{ kip})}{(111.34 \text{ kip})}$$

$$Ratio = 0.00048795$$

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

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

$S_m$ - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
$M_n$ shall be the lesser of:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
$\phi M_n$ - 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:**

$M_{max} = 69.886 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(69.886 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.28$$

Status: **PASS**
Ratio: **0.280**

**Considering z-direction:**

$M_{max} = 0.20482 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

| | | | |
|---|---|---|---|
| | | $$Ratio = \frac{(0.20482 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00082058$$ | Status: **PASS**<br>Ratio: **0.000** |

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

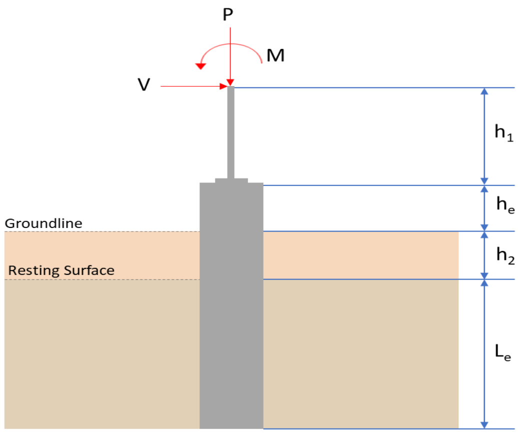
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 8.5\ \text{ft}$ - 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) | 9.453 | 14.390 |
| $V_x$ (kip) | -4.247 | -7.078 |
| $V_z$ (kip) | -0.031 | -0.054 |
| $M_x$ (kipft) | -0.136 | -0.238 |
| $M_z$ (kipft) | 63.210 | 107.760 |

**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,

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

$$H_o = \frac{(-4.247\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.67627\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(63.21\ \mathrm{kipft}) + ((-4.247\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.065\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.8631\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.031\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0049363\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.136\ \mathrm{kipft}) + ((-0.031\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.021656\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.119\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.8631\ \mathrm{ft}), (1.119\ \mathrm{ft})]$$

$$L_{e,req} = 7.863\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.863\ \mathrm{ft})}{(8.5\ \mathrm{ft})}$$

$$Ratio = 0.92506$$

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

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

$$q = \frac{(9.453 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.59081 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.59081 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.29541$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.125$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.67627 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 10.065 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.065 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.67627 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (10.065 \text{ kipft/ft})) + (4 \times (-0.67627 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.862 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.065 \text{ kipft/ft})) + (3 \times (-0.67627 \text{ kip/ft}) \times (8.5 \text{ ft}))]^{\ 2}}{(8.5 \text{ ft})^2 \times [(3 \times (10.065 \text{ kipft/ft})) + (2 \times (-0.67627 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.29408 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (10.065 \text{ kipft/ft})) + ((-0.67627 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.1944 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.862 \text{ ft})}{2}$$

$$p_a = 0.43965 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.29408\ \mathrm{kip/ft^2}\right)}{\left(0.43965\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.6689$$

Status: **PASS**
Ratio: **0.670**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1944\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93676$$

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

**Considering z-direction:**

$H_o = -0.0049363\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.021656\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.021656\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.021656\ \mathrm{kipft/ft})) + (4 \times (-0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.0659\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.021656\ \mathrm{kipft/ft})) + (3 \times (-0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^{\ 2}}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.021656\ \mathrm{kipft/ft})) + (2 \times (-0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.00084402\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.021656\ \mathrm{kipft/ft})) + ((-0.0049363\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 0.0001124\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0659\ \mathrm{ft})}{2}$$

$$p_a = 0.45494\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00084402\ \mathrm{kip/ft^2}\right)}{\left(0.45494\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0018552$$

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

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

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.5\ \mathrm{ft})$$

$$p_s = 1.275\ \mathrm{kip/ft^2}$$

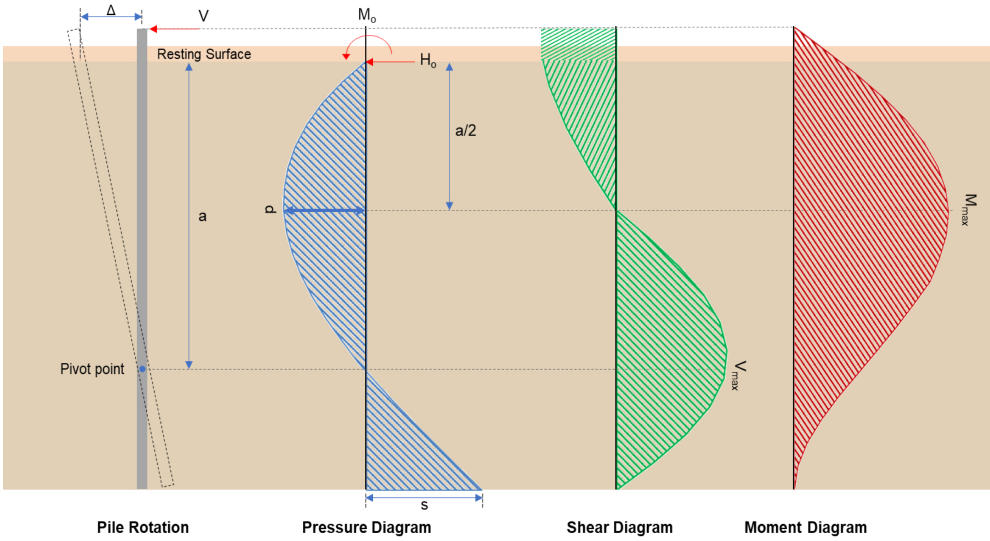
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0001124\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000088158$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-7.078\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1271\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(107.76\ \mathrm{kipft}) + ((-7.078\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 17.159\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(17.159\ \mathrm{kipft/ft})}{(-1.1271\ \mathrm{kip/ft})}$$

$$E = 15.225\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (17.159\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-1.1271\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (17.159\ \text{kipft/ft})) + (4 \times (-1.1271\ \text{kip/ft}) \times (8.5\ \text{ft}))}$$

$$a = 5.8588\ \text{ft}$$

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

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

$$V_{max} = ((-1.1271\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.225\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.8588\ \text{ft})}{(8.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.225\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.8588\ \text{ft})}{(8.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 17.263\ \text{kip}$$

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

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

$$M_{max} = ((-1.1271\ \text{kip/ft}) \times (48\ \text{in}) \times (8.5\ \text{ft})) \times \left[\left(\frac{(15.225\ \text{ft})}{(8.5\ \text{ft})} + \frac{(5.8588\ \text{ft})}{2 \times (8.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (15.225\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.8588\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.225\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.8588\ \text{ft})}{2 \times (8.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 69.886\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.054\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0085987\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.238\ \text{kipft}) + ((-0.054\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.037898\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.037898\ \text{kipft/ft})}{(-0.0085987\ \text{kip/ft})}$$

$$E = 4.4074\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.037898\ \text{kipft/ft}) \times (8.5\ \text{ft})) + \left(3 \times (-0.0085987\ \text{kip/ft}) \times (8.5\ \text{ft})^2\right)}{(6 \times (0.037898\ \text{kipft/ft})) + (4 \times (-0.0085987\ \text{kip/ft}) \times (8.5\ \text{ft}))}$$

$$a = 6.0651\ \text{ft}$$

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

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

$$V_{max} = ((-0.0085987\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.4074\text{ ft})}{(8.5\text{ ft})} + 3\right) \times \left(\frac{(6.0651\text{ ft})}{(8.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.4074\text{ ft})}{(8.5\text{ ft})} + 2\right) \times \left(\frac{(6.0651\text{ ft})}{(8.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.054462\text{ kip}$$

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

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

$$M_{max} = ((-0.0085987\text{ kip/ft}) \times (48\text{ in}) \times (8.5\text{ ft})) \times \left[\left(\frac{(4.4074\text{ ft})}{(8.5\text{ ft})} + \frac{(6.0651\text{ ft})}{2 \times (8.5\text{ ft})}\right) - \left[\left(\frac{4 \times (4.4074\text{ ft})}{(8.5\text{ ft})} + 3\right) \times \left(\frac{(6.0651\text{ ft})}{2 \times (8.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.4074\text{ ft})}{(8.5\text{ ft})} + 2\right) \times \left(\frac{(6.0651\text{ ft})}{2 \times (8.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.20537\text{ kipft}$$

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.39\text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\text{ ksi}) \times \left(2304\text{ in}^2\right)\right)}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, \left(0.08 \times \left(2304\text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.118\text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.118\text{ in}^2\right), \left(0.0018 \times \left(2304\text{ in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 14$$

$A_{st}$ - 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

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

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

$$Ratio = 0.96556$$

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

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

$$Ratio = \frac{(14.39\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0053791$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ , $P = 14.39 \text{ kip} \rightarrow 14390 \text{ lbf}$ ,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14390 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.4 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.4 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.4 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.4 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.34 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 17.263 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

| | | | |
|---|---|---|---|
| | $$Ratio = \frac{(17.263 \text{ kip})}{(111.34 \text{ kip})}$$ $$Ratio = 0.15504$$ | Status: **PASS** Ratio: **0.160** |
| | **Considering z-direction:** $V_{max} = 0.054462 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.054462 \text{ kip})}{(111.34 \text{ kip})}$$ $$Ratio = 0.00048913$$ | Status: **PASS** Ratio: **0.000** |
| 14.5.2.1b | **Flexural Strength (ACI 318-19, LRFD)** $S_m$ - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: $M_n$ shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, $\phi M_n$ - 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:** $M_{max} = 69.886 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(69.886 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.28$$ | Status: **PASS** Ratio: **0.280** |
| | **Considering z-direction:** $M_{max} = 0.20537 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ | |

| | | |
|---|---|---|
| | $$Ratio = \frac{(0.20537\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00082281$$ | Status: **PASS**<br>Ratio: **0.000** |