# Your Project Calculations

Project Name: MTSOLAR_I290HG4G1ED2

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_I290HG4G1ED2&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=Gv38cmDqtqTN642g1VIrwqj7JCaKJ7c5eUcbMBD8tLd5aimle2FV4bZzbhXwRqEd

## Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 4P-17-8TOP-HD-45-L-4Hx9W-AL26 |
| **Duty Classification:** | HD |
| **Module Width:** | 44.60 in |
| **Module Length:** | 89.20in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 9 |
| **Total Number of Modules:** | 36 |
| **Desired Tilt Angle:** | 31 |
| **Front Edge Clearance:** | 10 |
| **Total Array Height at Tilt:** | 17.70 ft |
| **Total Frame Length:** | 66.00 ft |
| **Frame Weight:** | 4586 lbs |
| **Array Dimensions N/S:** | 15.03 ft |
| **Array Dimensions E/W:** | 67.65 ft |
| **Rail Length:** | 180.40 in |
| **Rail Spacing:** | 3.72 ft |
| **Rail Check:** | Not Checked |

## Support Specifications

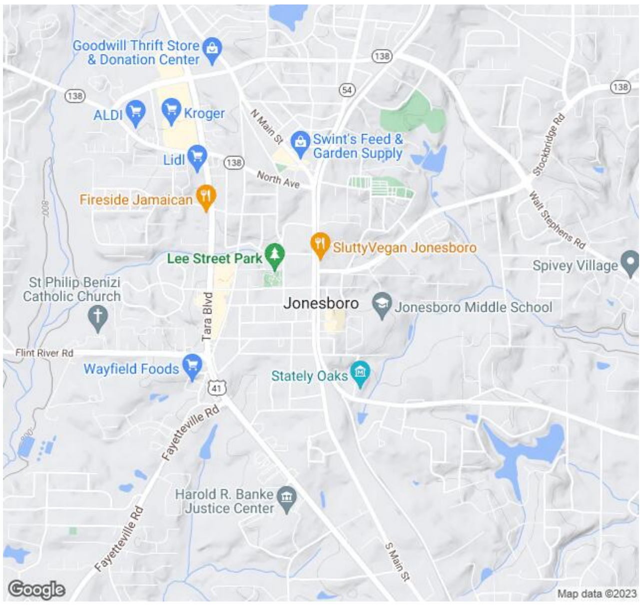
| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 80 |
| **Pole Length above Grade:** | 13.87 ft |
| **Number of Poles:** | 4 |
| **Pole Spacing:** | 17 ft |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 7.50 ft<br>Pile 2: 7.50 ft<br>Pile 3: 7.50 ft<br>Pile 4: 7.50 ft |
| **Foundation Volume:** | 17.778 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.086096 kip |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | D |
| **Soil Classification:** | sand |
| **Site Location:** | Jonesboro, GA 30236, USA |
| **Wind Speed:** | 99 mph |
| **Snow Load:** | Jonesboro, GA 30236, USA psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.001906 ksf |




### Design Disclaimer

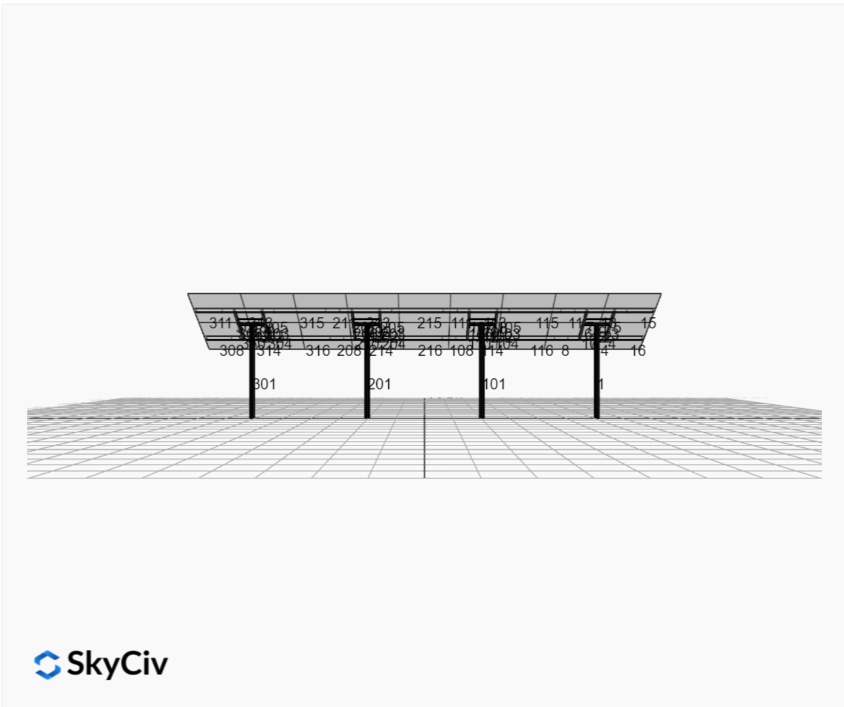
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

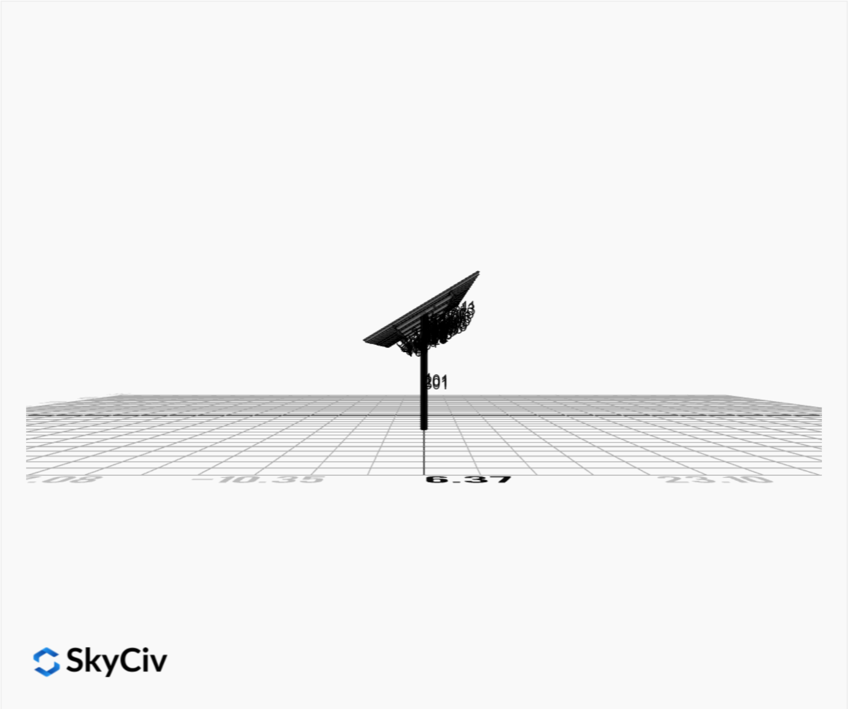
### AutoDesigner Input

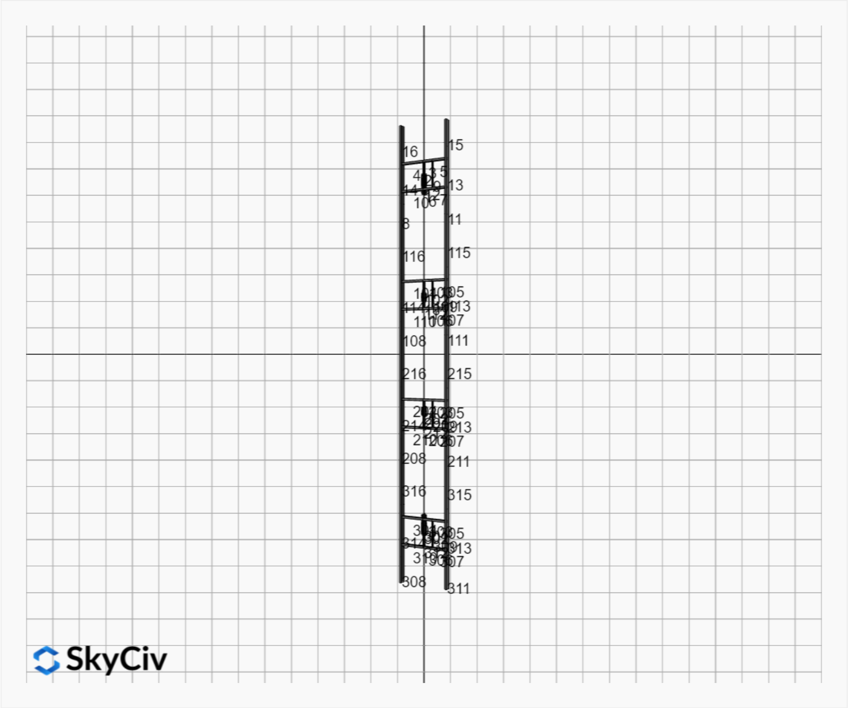
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_I290HG4G1ED2","site_address":"Jonesboro, GA 30236, USA","module_width":44.6,"module_length":89.2,"number_rows":"4","number_columns":9,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":31,"ground_clearance":10,"risk_category":"I","exposure_category":"D","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

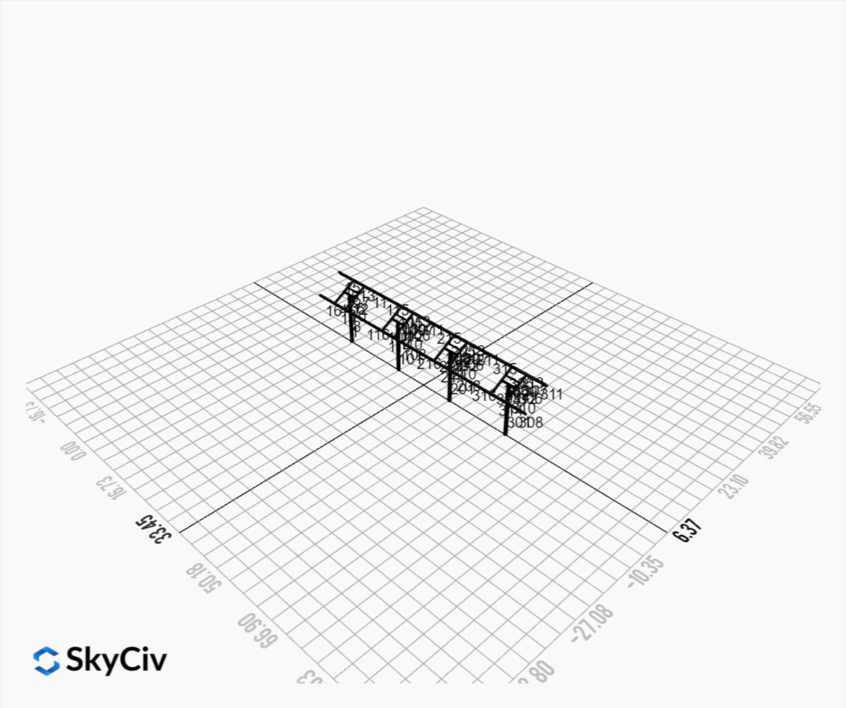
**Design Notes:**

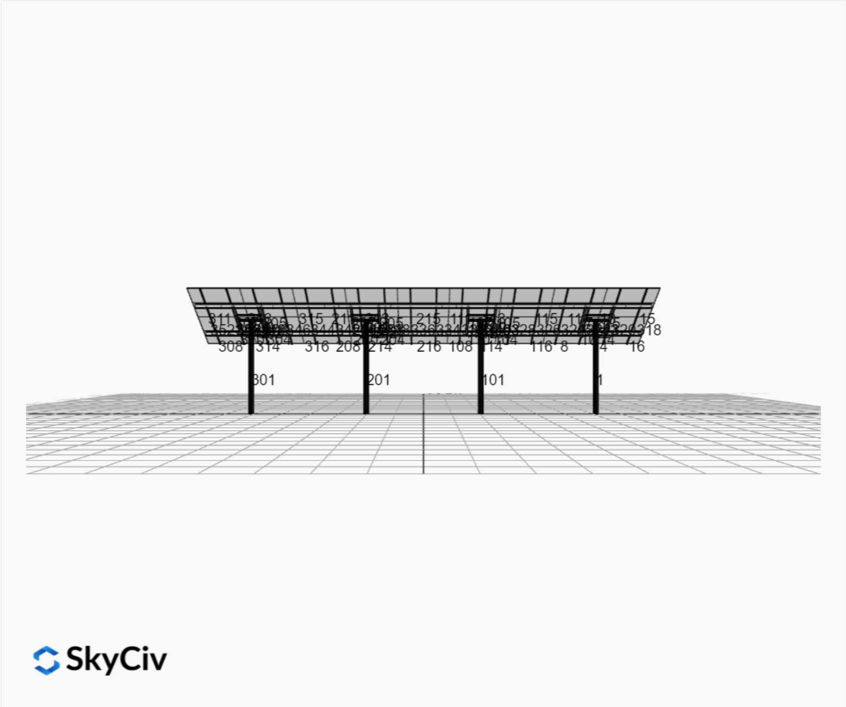
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



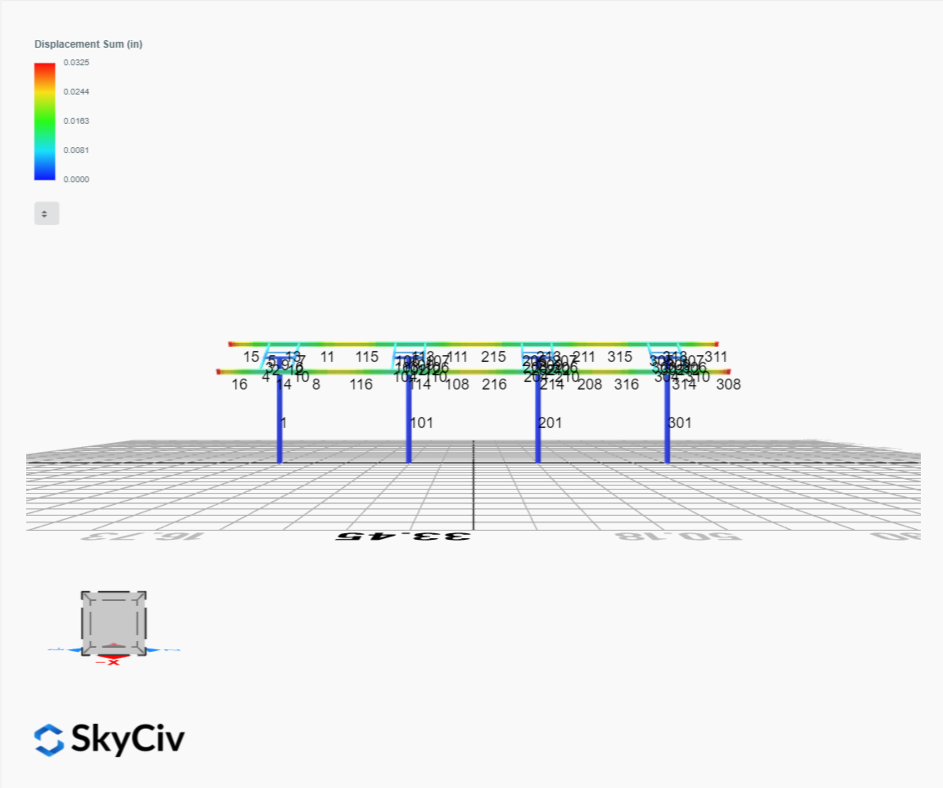


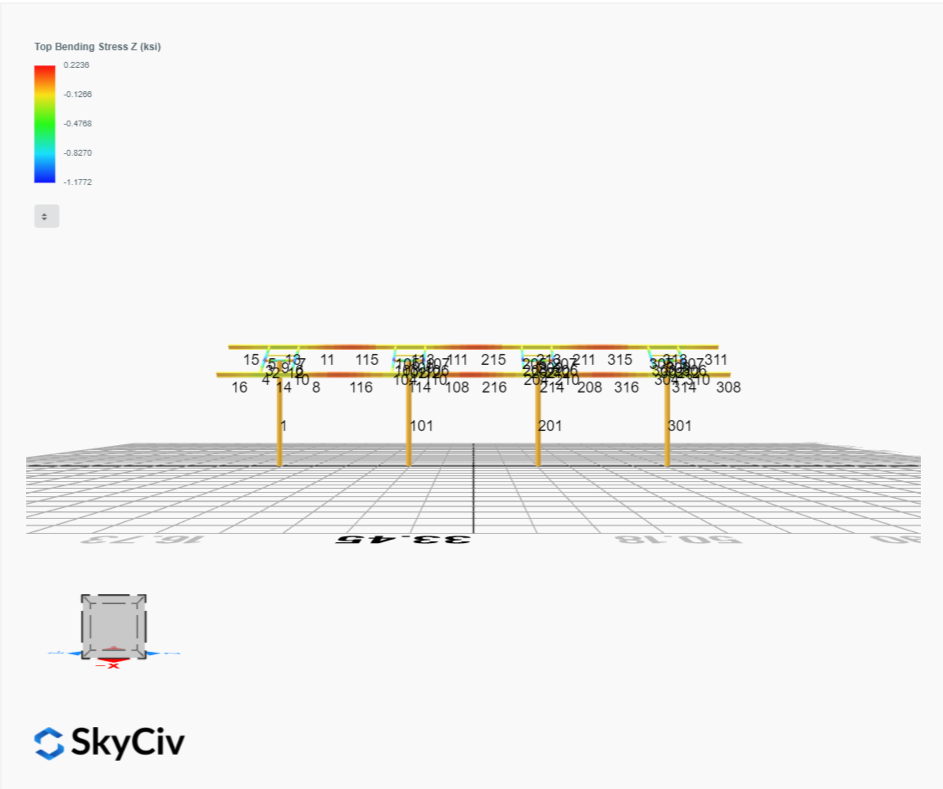


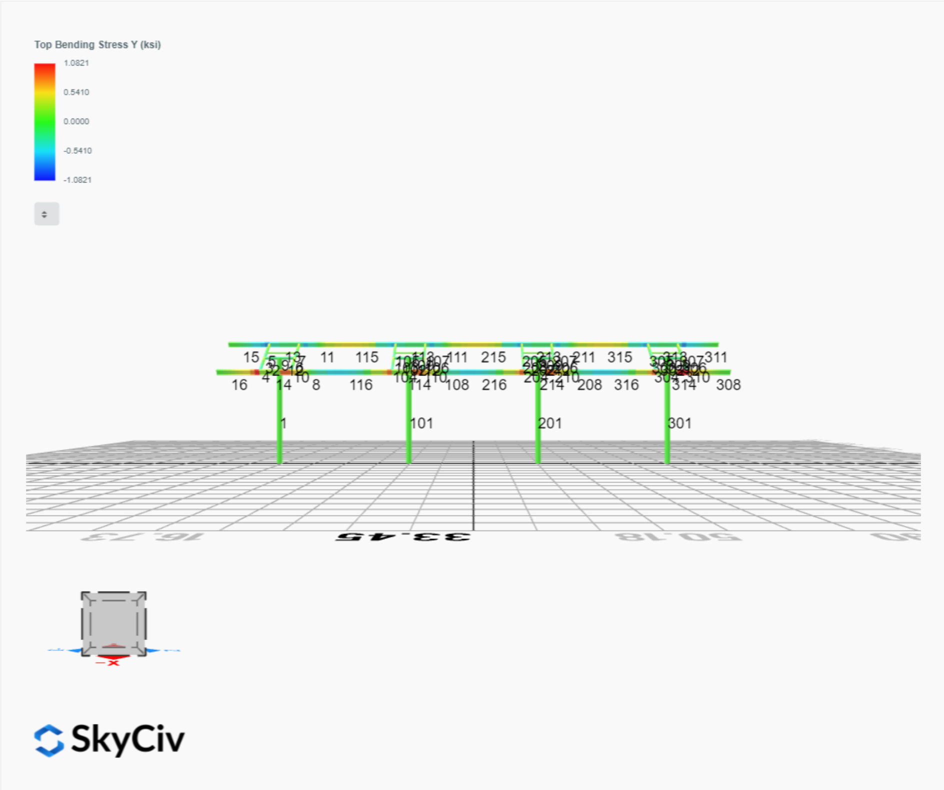


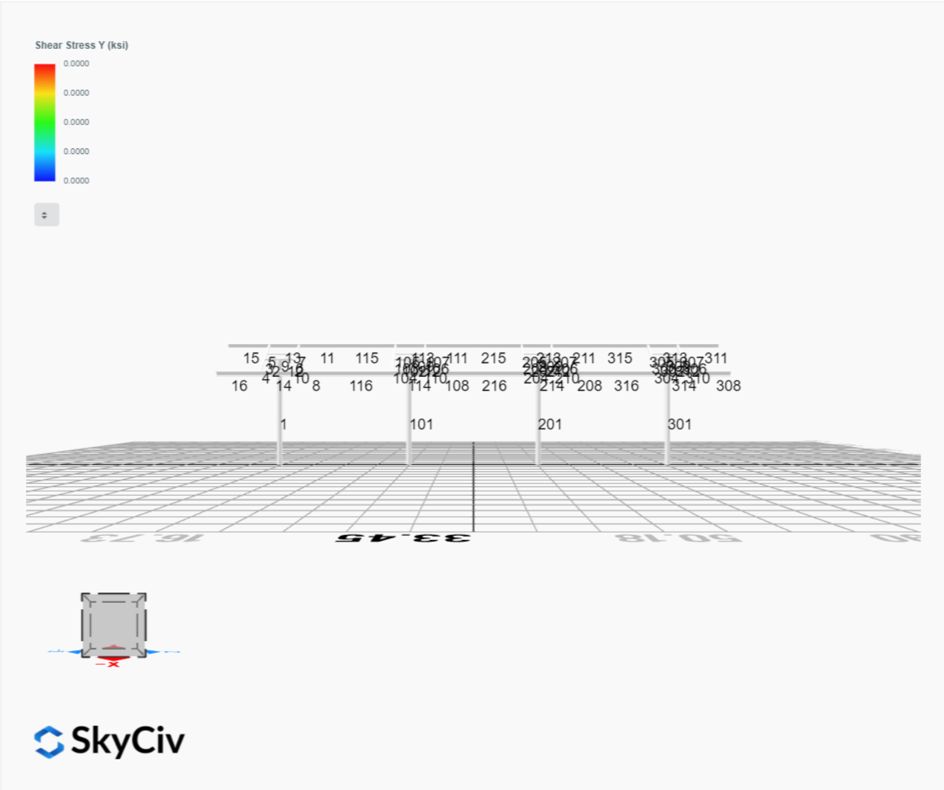


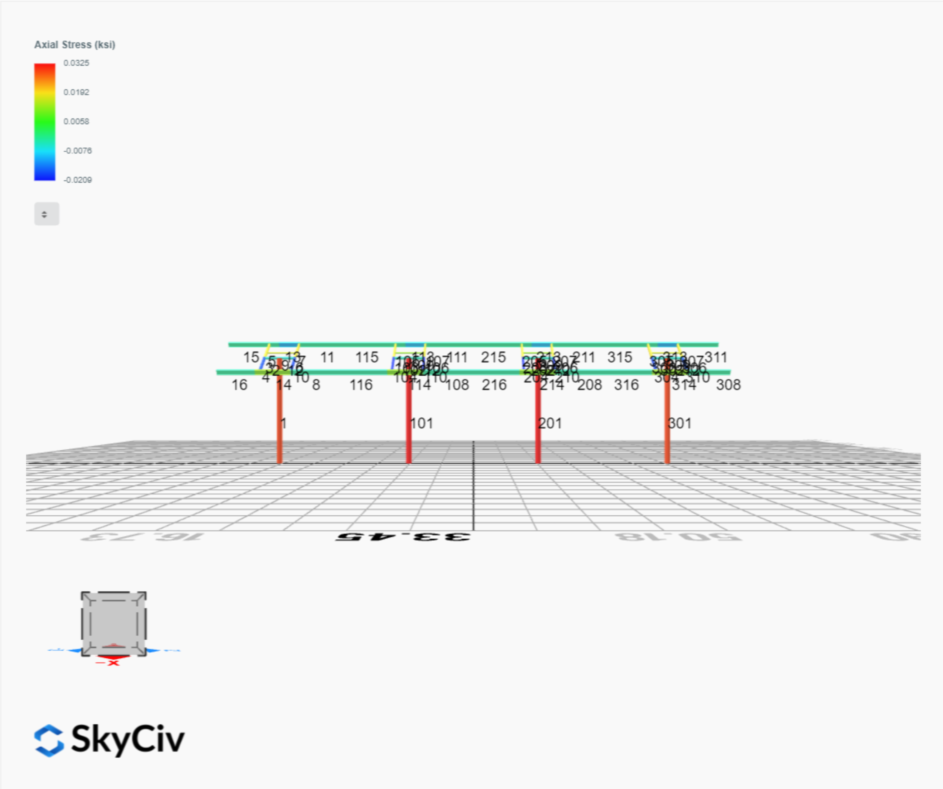
## FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
1.0821
0.5410
0.0000
-0.5410
-1.0821
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
SkyCiv


Axial Stress (ksi)
0.0325
0.0192
0.0058
-0.0076
-0.0209
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 | -0.0044 | 2.2628 | -0.0049 | -0.0190 | 0.0305 | 0.0833 |
| ULS: 2. D + L | -0.0044 | 2.2628 | -0.0049 | -0.0190 | 0.0305 | 0.0833 |
| ULS: 3. D + (S or Lr or R) | -0.0056 | 2.6583 | -0.0063 | -0.0240 | 0.0387 | 0.0988 |
| ULS: 3. D + (S or Lr or R) | -0.0044 | 2.2628 | -0.0049 | -0.0190 | 0.0305 | 0.0833 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0053 | 2.5594 | -0.0059 | -0.0228 | 0.0367 | 0.0949 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0044 | 2.2628 | -0.0049 | -0.0190 | 0.0305 | 0.0833 |
| ULS: 5b. D + 0.7E | -0.0044 | 2.2628 | -0.0049 | -0.0190 | 0.0305 | 0.0833 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0053 | 2.5594 | -0.0059 | -0.0228 | 0.0367 | 0.0949 |
| ULS: 8. 0.6D + 0.7E | -0.0026 | 1.3577 | -0.0030 | -0.0114 | 0.0183 | 0.0500 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.9607 | 7.1585 | -0.0182 | -0.0740 | 0.0583 | 42.2405 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.9607 | 7.1585 | -0.0182 | -0.0740 | 0.0583 | 42.2405 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.5201 | -1.9196 | 0.0072 | 0.0309 | 0.0033 | -34.2470 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.1051 | -1.2247 | 0.0021 | 0.0105 | 0.0213 | -38.4932 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2225 | 6.2312 | -0.0159 | -0.0640 | 0.0576 | 31.7128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2225 | 6.2312 | -0.0159 | -0.0640 | 0.0576 | 31.7128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.8881 | -0.5774 | 0.0032 | 0.0146 | 0.0163 | -25.6528 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.5768 | -0.0562 | -0.0006 | -0.0007 | 0.0298 | -28.8375 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2216 | 5.9346 | -0.0149 | -0.0603 | 0.0514 | 31.7012 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2216 | 5.9346 | -0.0149 | -0.0603 | 0.0514 | 31.7012 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.8889 | -0.8740 | 0.0042 | 0.0184 | 0.0101 | -25.6644 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.5777 | -0.3528 | 0.0003 | 0.0031 | 0.0236 | -28.8491 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.9589 | 6.2534 | -0.0163 | -0.0664 | 0.0461 | 42.2072 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.9589 | 6.2534 | -0.0163 | -0.0664 | 0.0461 | 42.2072 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.5218 | -2.8247 | 0.0092 | 0.0385 | -0.0089 | -34.2803 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.1069 | -2.1298 | 0.0041 | 0.0181 | 0.0091 | -38.5265 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 11.0728 |
| Shear X | -4.9335 |
| Shear Z | -0.0285 |
| Moment X | -0.1163 |
| Moment Y (Twist) | 0.0861 |
| Moment Z | 71.0575 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.1585 |
| Shear X | -2.9607 |
| Shear Z | -0.0182 |
| Moment X | -0.0740 |
| Moment Y (Twist) | 0.0583 |
| Moment Z | 42.2405 |

## 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 | 0.0044 | 2.3344 | 0.0017 | 0.0072 | -0.0048 | -0.0308 |
| ULS: 2. D + L | 0.0044 | 2.3344 | 0.0017 | 0.0072 | -0.0048 | -0.0308 |
| ULS: 3. D + (S or Lr or R) | 0.0056 | 2.7494 | 0.0022 | 0.0092 | -0.0061 | -0.0460 |
| ULS: 3. D + (S or Lr or R) | 0.0044 | 2.3344 | 0.0017 | 0.0072 | -0.0048 | -0.0308 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0053 | 2.6457 | 0.0021 | 0.0087 | -0.0058 | -0.0422 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0044 | 2.3344 | 0.0017 | 0.0072 | -0.0048 | -0.0308 |
| ULS: 5b. D + 0.7E | 0.0044 | 2.3344 | 0.0017 | 0.0072 | -0.0048 | -0.0308 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0053 | 2.6457 | 0.0021 | 0.0087 | -0.0058 | -0.0422 |
| ULS: 8. 0.6D + 0.7E | 0.0026 | 1.4006 | 0.0010 | 0.0043 | -0.0029 | -0.0185 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.0435 | 7.4314 | 0.0180 | 0.0731 | -0.0667 | 43.3972 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -3.0435 | 7.4314 | 0.0180 | 0.0731 | -0.0667 | 43.3972 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.6101 | -2.0213 | -0.0116 | -0.0465 | 0.0456 | -35.3757 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.1700 | -1.2932 | -0.0113 | -0.0452 | 0.0469 | -39.6574 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2807 | 6.4684 | 0.0143 | 0.0581 | -0.0522 | 32.5288 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2807 | 6.4684 | 0.0143 | 0.0581 | -0.0522 | 32.5288 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.9596 | -0.6211 | -0.0079 | -0.0316 | 0.0320 | -26.5508 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.6295 | -0.0750 | -0.0077 | -0.0307 | 0.0330 | -29.7621 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2816 | 6.1571 | 0.0139 | 0.0566 | -0.0513 | 32.5402 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2816 | 6.1571 | 0.0139 | 0.0566 | -0.0513 | 32.5402 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.9587 | -0.9324 | -0.0083 | -0.0331 | 0.0330 | -26.5395 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.6286 | -0.3863 | -0.0081 | -0.0321 | 0.0340 | -29.7507 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.0453 | 6.4976 | 0.0173 | 0.0702 | -0.0648 | 43.4095 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -3.0453 | 6.4976 | 0.0173 | 0.0702 | -0.0648 | 43.4095 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.6084 | -2.9550 | -0.0123 | -0.0494 | 0.0475 | -35.3633 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.1683 | -2.2269 | -0.0120 | -0.0481 | 0.0489 | -39.6450 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 11.5036 |
| Shear X | -5.0799 |
| Shear Z | 0.0296 |
| Moment X | 0.1203 |
| Moment Y (Twist) | 0.1104 |
| Moment Z | 73.0471 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.4314 |
| Shear X | -3.0453 |
| Shear Z | 0.0180 |
| Moment X | 0.0731 |
| Moment Y (Twist) | 0.0667 |
| Moment Z | 43.4095 |

## 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 | 0.0044 | 2.3344 | -0.0017 | -0.0072 | 0.0048 | -0.0308 |
| ULS: 2. D + L | 0.0044 | 2.3344 | -0.0017 | -0.0072 | 0.0048 | -0.0308 |
| ULS: 3. D + (S or Lr or R) | 0.0056 | 2.7494 | -0.0022 | -0.0092 | 0.0061 | -0.0460 |
| ULS: 3. D + (S or Lr or R) | 0.0044 | 2.3344 | -0.0017 | -0.0072 | 0.0048 | -0.0308 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0053 | 2.6457 | -0.0021 | -0.0087 | 0.0058 | -0.0422 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0044 | 2.3344 | -0.0017 | -0.0072 | 0.0048 | -0.0308 |
| ULS: 5b. D + 0.7E | 0.0044 | 2.3344 | -0.0017 | -0.0072 | 0.0048 | -0.0308 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0053 | 2.6457 | -0.0021 | -0.0087 | 0.0058 | -0.0422 |
| ULS: 8. 0.6D + 0.7E | 0.0026 | 1.4006 | -0.0010 | -0.0043 | 0.0029 | -0.0185 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -3.0435 | 7.4314 | -0.0180 | -0.0731 | 0.0667 | 43.3972 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -3.0435 | 7.4314 | -0.0180 | -0.0731 | 0.0667 | 43.3972 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.6101 | -2.0213 | 0.0116 | 0.0466 | -0.0455 | -35.3757 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.1700 | -1.2932 | 0.0113 | 0.0452 | -0.0469 | -39.6574 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2807 | 6.4684 | -0.0143 | -0.0581 | 0.0523 | 32.5288 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2807 | 6.4684 | -0.0143 | -0.0581 | 0.0523 | 32.5288 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.9596 | -0.6211 | 0.0079 | 0.0316 | -0.0320 | -26.5508 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.6295 | -0.0750 | 0.0077 | 0.0307 | -0.0330 | -29.7621 |

| 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 | -2.2816 | 6.1571 | -0.0139 | -0.0566 | 0.0513 | 32.5402 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2816 | 6.1571 | -0.0139 | -0.0566 | 0.0513 | 32.5402 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.9587 | -0.9324 | 0.0083 | 0.0331 | -0.0330 | -26.5395 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.6286 | -0.3863 | 0.0081 | 0.0321 | -0.0340 | -29.7507 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -3.0453 | 6.4976 | -0.0173 | -0.0702 | 0.0648 | 43.4095 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -3.0453 | 6.4976 | -0.0173 | -0.0702 | 0.0648 | 43.4095 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.6084 | -2.9550 | 0.0123 | 0.0494 | -0.0475 | -35.3633 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.1683 | -2.2269 | 0.0120 | 0.0481 | -0.0489 | -39.6450 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 11.5036 |
| Shear X | -5.0799 |
| Shear Z | -0.0297 |
| Moment X | -0.1202 |
| Moment Y (Twist) | 0.1105 |
| Moment Z | 73.0472 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 7.4314 |
| Shear X | -3.0453 |
| Shear Z | -0.0180 |
| Moment X | -0.0731 |
| Moment Y (Twist) | 0.0667 |
| Moment Z | 43.4095 |

## 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 | -0.0044 | 2.2628 | 0.0049 | 0.0190 | -0.0305 | 0.0833 |
| ULS: 2. D + L | -0.0044 | 2.2628 | 0.0049 | 0.0190 | -0.0305 | 0.0833 |
| ULS: 3. D + (S or Lr or R) | -0.0056 | 2.6583 | 0.0063 | 0.0240 | -0.0387 | 0.0988 |
| ULS: 3. D + (S or Lr or R) | -0.0044 | 2.2628 | 0.0049 | 0.0190 | -0.0305 | 0.0833 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0053 | 2.5594 | 0.0059 | 0.0228 | -0.0367 | 0.0949 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0044 | 2.2628 | 0.0049 | 0.0190 | -0.0305 | 0.0833 |
| ULS: 5b. D + 0.7E | -0.0044 | 2.2628 | 0.0049 | 0.0190 | -0.0305 | 0.0833 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0053 | 2.5594 | 0.0059 | 0.0228 | -0.0367 | 0.0949 |
| ULS: 8. 0.6D + 0.7E | -0.0026 | 1.3577 | 0.0030 | 0.0114 | -0.0183 | 0.0500 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.9607 | 7.1585 | 0.0182 | 0.0740 | -0.0583 | 42.2405 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.9607 | 7.1585 | 0.0182 | 0.0740 | -0.0583 | 42.2405 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.5201 | -1.9196 | -0.0072 | -0.0309 | -0.0033 | -34.2470 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.1051 | -1.2247 | -0.0021 | -0.0104 | -0.0213 | -38.4932 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2225 | 6.2312 | 0.0159 | 0.0640 | -0.0576 | 31.7128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2225 | 6.2312 | 0.0159 | 0.0640 | -0.0576 | 31.7128 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.8881 | -0.5774 | -0.0032 | -0.0146 | -0.0162 | -25.6528 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.5768 | -0.0562 | 0.0006 | 0.0007 | -0.0298 | -28.8375 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.2216 | 5.9346 | 0.0149 | 0.0603 | -0.0514 | 31.7012 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.2216 | 5.9346 | 0.0149 | 0.0603 | -0.0514 | 31.7012 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.8889 | -0.8740 | -0.0042 | -0.0184 | -0.0101 | -25.6644 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.5777 | -0.3528 | -0.0003 | -0.0031 | -0.0236 | -28.8491 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.9589 | 6.2534 | 0.0163 | 0.0664 | -0.0461 | 42.2072 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.9589 | 6.2534 | 0.0163 | 0.0664 | -0.0461 | 42.2072 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.5218 | -2.8247 | -0.0092 | -0.0385 | 0.0089 | -34.2803 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.1069 | -2.1298 | -0.0041 | -0.0181 | -0.0091 | -38.5265 |

### Worst Case Reactions LRFD

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
| --- | --- |
| Axial | 11.0728 |
| Shear X | -4.9335 |
| Shear Z | 0.0286 |
| Moment X | 0.1164 |
| Moment Y (Twist) | 0.0861 |
| Moment Z | 71.0581 |

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

| Result | Value (kip, kip-ft) |
| --- | --- |
| Axial | 7.1585 |
| Shear X | -2.9607 |
| Shear Z | 0.0182 |
| Moment X | 0.0740 |
| Moment Y (Twist) | 0.0583 |
| Moment Z | 42.2405 |

## Project Details

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

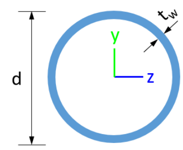
User Name: sales@mtsolar.us
Unit System: imperial

## Design Input Information

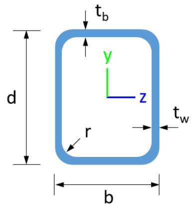
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

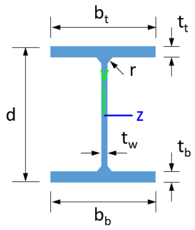
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | | |
| 10 | 8in Pipe Sch 80 | 8.63 | 0.50 | | | | | |




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




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

| Section Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | Name | A ($in^2$) | J ($in^4$) | $I_{yp}$ ($in^4$) | $I_{zp}$ ($in^4$) | $I_w$ ($in^6$) | $S_{yp}$ ($in^3$) | $S_{zp}$ ($in^3$) |
| 2 | 2in Pipe Sch 80 | 1.48 | 1.74 | 0.87 | 0.87 | 0.00 | 1.02 | 1.02 |
| 5 | 4in Pipe Sch 80 | 4.41 | 19.22 | 9.61 | 9.61 | 0.00 | 5.85 | 5.85 |
| 10 | 8in Pipe Sch 80 | 12.76 | 211.43 | 105.72 | 105.72 | 0.00 | 33.05 | 33.05 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 92.39 | 2.96 | 4.21 |
| 19 | W8x10 | 2.96 | 0.04 | 2.09 | 30.80 | 30.90 | 1.66 | 8.87 |

| **Member Properties** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 10 | 29.13 | 29.13 | 13.87 | - | 300 | 200 | 1 |
| 2 | 5 | 4.20 | 4.20 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 1.92,1.92,1.92,1.92,1.92,1.92,1.93,1.93,1.94,1.51,1.93,1.93,1.94,1.57,1.93,1.93,1.94,2.04,1.93,1.93,1.94,2.33,1.93,1.93,1.93,1.64 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 1.91,1.91,1.91,1.91,1.91,1.91,1.99,1.99,2.02,2.03,1.99,1.99,2.01,2.03,1.97,1.97,2.04,2.04,1.98,1.98,2.03,2.03,1.99,1.99,2.01,2.03 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.11,1.12,1.11,1.11,1.11,1.12 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.11,1.07,1.11,1.11,1.11,1.08,1.12,1.12,1.11,1.42,1.11,1.11,1.11,3.48,1.11,1.11,1.11,1.09 | 300 | 200 | 1 |
| 15 | 19 | 7.88 | 7.88 | 3.75 | 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 | 19 | 7.88 | 7.88 | 3.75 | 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 | 29.13 | 29.13 | 13.87 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 108 | 19 | 1.33 | 1.33 | 2.05 | 1.59,1.59,1.59,1.60,1.59,1.59,1.59,1.59,1.58,1.36,1.59,1.59,1.58,1.39,1.59,1.59,1.58,1.79,1.59,1.59,1.58,2.05,1.59,1.59,1.59,1.44 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 111 | 19 | 1.33 | 1.33 | 2.05 | 1.62,1.63,1.62,1.63,1.62,1.62,1.56,1.56,1.54,1.56,1.56,1.56,1.54,1.56,1.57,1.57,1.50,1.54,1.57,1.57,1.52,1.55,1.56,1.56,1.55,1.57 | 300 | 200 | 1 |
| 112 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.07,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.47,1.06,1.06,1.06,3.79,1.06,1.06,1.06,1.05 | 300 | 200 | 1 |
| 115 | 19 | 4.84 | 4.84 | 7.45 | 1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.11,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12 | 300 | 200 | 1 |
| 116 | 19 | 4.84 | 4.84 | 7.45 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.10,1.13,1.13,1.13,1.11,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.17,1.13,1.13,1.13,1.11 | 300 | 200 | 1 |
| 201 | 10 | 29.13 | 29.13 | 13.87 | - | 300 | 200 | 1 |
| 202 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 204 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 205 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 206 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 207 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 208 | 19 | 1.33 | 1.33 | 2.05 | 1.63,1.63,1.63,1.63,1.63,1.63,1.62,1.62,1.62,1.41,1.62,1.62,1.62,1.44,1.62,1.62,1.61,1.80,1.62,1.62,1.61,2.03,1.62,1.62,1.62,1.49 | 300 | 200 | 1 |
| 209 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 211 | 19 | 1.33 | 1.33 | 2.05 | 1.67,1.67,1.67,1.67,1.67,1.67,1.58,1.58,1.55,1.57,1.58,1.58,1.56,1.58,1.60,1.60,1.50,1.54,1.59,1.59,1.53,1.56,1.58,1.58,1.56,1.58 | 300 | 200 | 1 |
| 212 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.07,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07 | 300 | 200 | 1 |
| 214 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.06,1.06,1.06,1.05,1.06,1.06,1.06,1.47,1.06,1.06,1.06,3.82,1.06,1.06,1.06,1.05 | 300 | 200 | 1 |
| 215 | 19 | 4.84 | 4.84 | 7.45 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.13,1.13,1.13,1.12,1.13,1.13,1.13,1.12,1.12,1.13,1.13,1.12,1.13,1.13,1.13,1.12,1.13 | 300 | 200 | 1 |
| 216 | 19 | 4.84 | 4.84 | 7.45 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.10,1.13,1.13,1.13,1.10,1.13,1.13,1.13,1.15,1.13,1.13,1.13,1.19,1.13,1.13,1.13,1.11 | 300 | 200 | 1 |
| 301 | 10 | 29.13 | 29.13 | 13.87 | - | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 302 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 303 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 304 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 305 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 306 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 307 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 308 | 19 | 7.88 | 7.88 | 3.75 | 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 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 310 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.69,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.63,1.67,1.67,1.65,1.70,1.67,1.67,1.65,1.75,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 311 | 19 | 7.88 | 7.88 | 3.75 | 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 | 5 | 4.20 | 4.20 | 2.00 | - | 300 | 200 | 1 |
| 313 | 19 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.11,1.12,1.11,1.11,1.11,1.12 | 300 | 200 | 1 |
| 314 | 19 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.11,1.07,1.11,1.11,1.11,1.08,1.12,1.12,1.11,1.42,1.12,1.12,1.11,3.45,1.11,1.11,1.11,1.09 | 300 | 200 | 1 |
| 315 | 19 | 4.84 | 4.84 | 7.45 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17 | 300 | 200 | 1 |
| 316 | 19 | 4.84 | 4.84 | 7.45 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.12,1.16,1.16,1.16,1.13,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.14 | 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 | 195.45 | 123.94 | 123.94 | 172.30 | 172.30 |
| 2 | 198.33 | 182.14 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 104.94 | 25.44 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 104.94 | 24.52 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 574.32 | 195.45 | 123.94 | 123.94 | 172.30 | 172.30 |
| 102 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 104 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 105 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 106 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 107 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 108 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 109 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 110 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 111 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 104.94 | 24.29 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 104.94 | 24.06 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 93.89 | 25.56 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 93.89 | 25.33 | 6.12 | 40.24 | 43.62 |
| 201 | 574.32 | 195.45 | 123.94 | 123.94 | 172.30 | 172.30 |
| 202 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 203 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 204 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 205 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 206 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 207 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 208 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 209 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 210 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 211 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 212 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 213 | 133.20 | 104.94 | 24.29 | 6.12 | 40.24 | 43.62 |
| 214 | 133.20 | 104.94 | 24.06 | 6.12 | 40.24 | 43.62 |
| 215 | 133.20 | 93.89 | 25.79 | 6.12 | 40.24 | 43.62 |
| 216 | 133.20 | 93.89 | 25.33 | 6.12 | 40.24 | 43.62 |
| 301 | 574.32 | 195.45 | 123.94 | 123.94 | 172.30 | 172.30 |
| 302 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 303 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 304 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 305 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 306 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 307 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 308 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 309 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 310 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 311 | 133.20 | 52.83 | 32.87 | 6.12 | 40.24 | 43.62 |
| 312 | 198.33 | 182.14 | 21.95 | 21.95 | 59.50 | 59.50 |
| 313 | 133.20 | 104.94 | 25.44 | 6.12 | 40.24 | 43.62 |
| 314 | 133.20 | 104.94 | 24.52 | 6.12 | 40.24 | 43.62 |
| 315 | 133.20 | 93.89 | 26.71 | 6.12 | 40.24 | 43.62 |
| 316 | 133.20 | 93.89 | 25.79 | 6.12 | 40.24 | 43.62 |

## 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 | 0.057 | 0.573 | 0.002 | 0.029 | 0.000 | 0.603 | #13 | 0.607 | Not Required | Pass |
| 2 | 0.000 | 0.417 | 0.213 | 0.088 | 0.042 | 0.630 | #13 | 0.114 | Not Required | Pass |
| 3 | 0.003 | 0.679 | 0.020 | 0.068 | 0.005 | 0.698 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.003 | 0.674 | 0.027 | 0.068 | 0.008 | 0.694 | #13 | 0.080 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 0.003 | 0.674 | 0.037 | 0.068 | 0.008 | 0.694 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.003 | 0.421 | 0.038 | 0.068 | 0.009 | 0.427 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.003 | 0.670 | 0.021 | 0.067 | 0.004 | 0.686 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.003 | 0.416 | 0.039 | 0.067 | 0.010 | 0.422 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.000 | 0.061 | 0.027 | 0.042 | 0.004 | 0.086 | #13 | 0.063 | Not Required | Pass |
| 9 | 0.002 | 0.064 | 0.040 | 0.001 | 0.000 | 0.104 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.003 | 0.660 | 0.039 | 0.066 | 0.009 | 0.684 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.000 | 0.061 | 0.027 | 0.043 | 0.004 | 0.086 | #13 | 0.095 | Not Required | Pass |
| 12 | 0.000 | 0.404 | 0.209 | 0.086 | 0.041 | 0.613 | #13 | 0.035 | Not Required | Pass |
| 13 | 0.002 | 0.222 | 0.094 | 0.058 | 0.006 | 0.283 | #13 | 0.286 | Not Required | Pass |
| 14 | 0.002 | 0.223 | 0.094 | 0.057 | 0.006 | 0.282 | #13 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.074 | 0.044 | 0.032 | 0.003 | 0.110 | #13 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.074 | 0.044 | 0.032 | 0.003 | 0.109 | #13 | Not Required | Not Required | Pass |
| 101 | 0.059 | 0.589 | 0.002 | 0.029 | 0.000 | 0.620 | #13 | 0.607 | Not Required | Pass |
| 102 | 0.000 | 0.416 | 0.213 | 0.090 | 0.042 | 0.629 | #13 | 0.053 | Not Required | Pass |
| 103 | 0.003 | 0.692 | 0.022 | 0.069 | 0.005 | 0.711 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.003 | 0.689 | 0.037 | 0.069 | 0.008 | 0.717 | #13 | 0.080 | Not Required | Pass |
| 105 | 0.003 | 0.429 | 0.037 | 0.069 | 0.009 | 0.436 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.003 | 0.706 | 0.023 | 0.071 | 0.006 | 0.725 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.003 | 0.438 | 0.035 | 0.070 | 0.009 | 0.445 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.000 | 0.077 | 0.025 | 0.041 | 0.004 | 0.097 | #13 | 0.095 | Not Required | Pass |
| 109 | 0.001 | 0.062 | 0.037 | 0.001 | 0.000 | 0.100 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.003 | 0.701 | 0.035 | 0.070 | 0.008 | 0.721 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.000 | 0.079 | 0.025 | 0.041 | 0.004 | 0.099 | #13 | 0.095 | Not Required | Pass |
| 112 | 0.000 | 0.430 | 0.218 | 0.091 | 0.043 | 0.647 | #13 | 0.035 | Not Required | Pass |
| 113 | 0.002 | 0.164 | 0.088 | 0.056 | 0.006 | 0.219 | #13 | 0.286 | Not Required | Pass |
| 114 | 0.002 | 0.171 | 0.088 | 0.056 | 0.006 | 0.223 | #13 | 0.190 | Not Required | Pass |
| 115 | 0.000 | 0.133 | 0.047 | 0.039 | 0.004 | 0.173 | #13 | 0.346 | Not Required | Pass |
| 116 | 0.000 | 0.132 | 0.048 | 0.039 | 0.004 | 0.170 | #13 | 0.231 | Not Required | Pass |
| 201 | 0.059 | 0.589 | 0.002 | 0.029 | 0.000 | 0.620 | #13 | 0.607 | Not Required | Pass |
| 202 | 0.000 | 0.430 | 0.218 | 0.091 | 0.043 | 0.648 | #13 | 0.035 | Not Required | Pass |
| 203 | 0.003 | 0.706 | 0.023 | 0.071 | 0.006 | 0.725 | #13 | 0.045 | Not Required | Pass |
| 204 | 0.003 | 0.701 | 0.035 | 0.070 | 0.008 | 0.721 | #13 | 0.080 | Not Required | Pass |
| 205 | 0.003 | 0.438 | 0.035 | 0.070 | 0.009 | 0.445 | #13 | 0.074 | Not Required | Pass |
| 206 | 0.003 | 0.692 | 0.022 | 0.069 | 0.005 | 0.711 | #13 | 0.045 | Not Required | Pass |
| 207 | 0.003 | 0.429 | 0.037 | 0.069 | 0.009 | 0.436 | #13 | 0.074 | Not Required | Pass |
| 208 | 0.000 | 0.070 | 0.028 | 0.039 | 0.004 | 0.086 | #13 | 0.063 | Not Required | Pass |
| 209 | 0.001 | 0.062 | 0.037 | 0.001 | 0.000 | 0.100 | #13 | 0.204 | Not Required | Pass |
| 210 | 0.003 | 0.689 | 0.037 | 0.069 | 0.008 | 0.717 | #13 | 0.080 | Not Required | Pass |
| 211 | 0.000 | 0.073 | 0.027 | 0.039 | 0.004 | 0.089 | #13 | 0.095 | Not Required | Pass |
| 212 | 0.000 | 0.416 | 0.213 | 0.090 | 0.042 | 0.629 | #13 | 0.053 | Not Required | Pass |
| 213 | 0.002 | 0.164 | 0.088 | 0.056 | 0.006 | 0.219 | #13 | 0.286 | Not Required | Pass |
| 214 | 0.002 | 0.171 | 0.088 | 0.056 | 0.006 | 0.223 | #13 | 0.286 | Not Required | Pass |
| 215 | 0.000 | 0.148 | 0.047 | 0.041 | 0.004 | 0.187 | #13 | 0.346 | Not Required | Pass |
| 216 | 0.000 | 0.145 | 0.048 | 0.041 | 0.004 | 0.184 | #13 | 0.346 | Not Required | Pass |
| 301 | 0.057 | 0.573 | 0.002 | 0.029 | 0.000 | 0.603 | #13 | 0.607 | Not Required | Pass |
| 302 | 0.000 | 0.404 | 0.209 | 0.086 | 0.041 | 0.613 | #13 | 0.035 | Not Required | Pass |
| 303 | 0.003 | 0.670 | 0.021 | 0.067 | 0.004 | 0.686 | #13 | 0.045 | Not Required | Pass |
| 304 | 0.003 | 0.660 | 0.039 | 0.066 | 0.009 | 0.684 | #13 | 0.080 | Not Required | Pass |
| 305 | 0.003 | 0.416 | 0.039 | 0.067 | 0.010 | 0.422 | #13 | 0.074 | Not Required | Pass |
| 306 | 0.003 | 0.679 | 0.020 | 0.068 | 0.005 | 0.698 | #13 | 0.045 | Not Required | Pass |
| 307 | 0.003 | 0.421 | 0.038 | 0.068 | 0.009 | 0.427 | #13 | 0.074 | Not Required | Pass |
| 308 | 0.000 | 0.074 | 0.044 | 0.032 | 0.003 | 0.109 | #13 | Not Required | Not Required | Pass |
| 309 | 0.002 | 0.064 | 0.040 | 0.001 | 0.000 | 0.104 | #13 | 0.204 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 310 | 0.003 | 0.674 | 0.037 | 0.068 | 0.008 | 0.694 | #13 | 0.080 | Not Required | Pass |
| 311 | 0.000 | 0.074 | 0.044 | 0.032 | 0.003 | 0.110 | #13 | Not Required | Not Required | Pass |
| 312 | 0.000 | 0.417 | 0.213 | 0.088 | 0.042 | 0.630 | #13 | 0.114 | Not Required | Pass |
| 313 | 0.002 | 0.222 | 0.094 | 0.058 | 0.006 | 0.283 | #13 | 0.190 | Not Required | Pass |
| 314 | 0.002 | 0.223 | 0.094 | 0.057 | 0.006 | 0.282 | #13 | 0.190 | Not Required | Pass |
| 315 | 0.000 | 0.129 | 0.048 | 0.043 | 0.004 | 0.168 | #13 | 0.346 | Not Required | Pass |
| 316 | 0.000 | 0.128 | 0.048 | 0.042 | 0.004 | 0.167 | #13 | 0.231 | 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 |
|---|---|---|

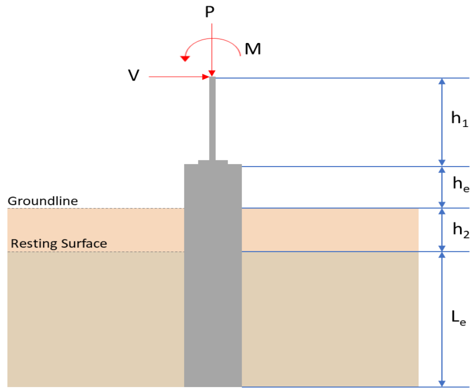
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.159 | 11.073 |
| $V_x$ (kip) | -2.961 | -4.933 |
| $V_z$ (kip) | -0.018 | -0.029 |
| $M_x$ (kipft) | -0.074 | -0.116 |
| $M_z$ (kipft) | 42.241 | 71.057 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.961\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.4715\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(42.241\ \mathrm{kipft}) + ((-2.961\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.7263\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 6.9833\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0028662\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.074\ \mathrm{kipft}) + ((-0.018\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.011783\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 0.92195\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.9833\ \mathrm{ft}), (0.92195\ \mathrm{ft})]$$

$$L_{e,req} = 6.983\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.983\ \mathrm{ft})}{(7.5\ \mathrm{ft})}$$

$$Ratio = 0.93107$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.159\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.44744\ \mathrm{kip/ft}^2$$

$q = 0.44744\ \mathrm{kip/ft}$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.44744\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.22372$$

Status: **PASS**
Ratio: **0.220**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.4715\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.7263\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.7263\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.4715\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.7263\ \mathrm{kipft/ft})) + (4 \times (-0.4715\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1622\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.7263\ \mathrm{kipft/ft})) + (3 \times (-0.4715\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.7263\ \mathrm{kipft/ft})) + (2 \times (-0.4715\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.27017\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (6.7263\ \mathrm{kipft/ft})) + ((-0.4715\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0577\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1622\ \mathrm{ft})}{2}$$

$$p_a = 0.38717\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27017\ \mathrm{kip/ft^2}\right)}{\left(0.38717\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.69782$$

Status: **PASS**
Ratio: **0.700**

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

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0577\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94021$$

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

**Considering z-direction:**

$H_o = -0.0028662\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011783\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011783\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.011783\ \mathrm{kipft/ft})) + (4 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.343\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011783\ \mathrm{kipft/ft})) + (3 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.011783\ \mathrm{kipft/ft})) + (2 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.00052552\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.011783\ \mathrm{kipft/ft})) + ((-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.00022081\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.343\ \mathrm{ft})}{2}$$

$$p_a = 0.40072\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00052552\ \mathrm{kip/ft^2}\right)}{\left(0.40072\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0013114$$

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

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

$$p_s = R\,L_e$$

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

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

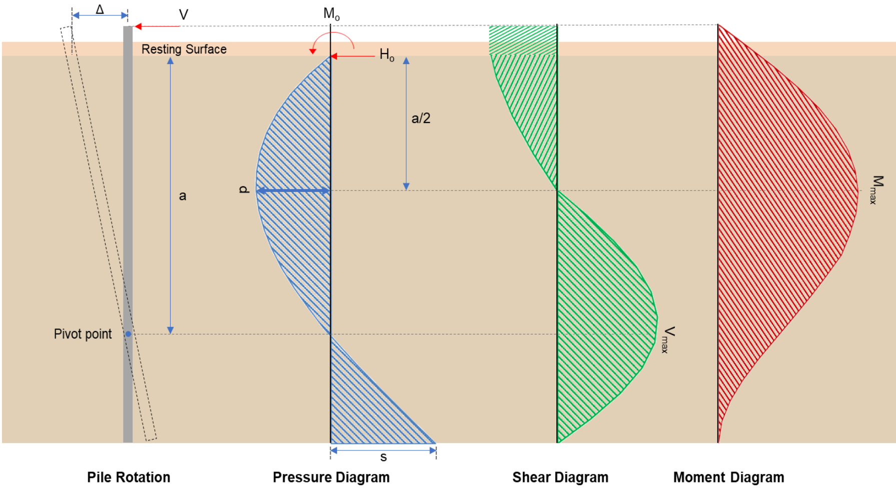
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00022081\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.00019627$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.933\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.78551\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(71.057\ \mathrm{kipft}) + ((-4.933\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.315\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(11.315\ \mathrm{kipft/ft})}{(-0.78551\ \mathrm{kip/ft})}$$

$$E = 14.404\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (11.315\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.78551\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (11.315\ \mathrm{kipft/ft})) + (4 \times (-0.78551\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.161\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.78551\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.404\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.161\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.404\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.161\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.752\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.78551 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(14.404 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.161 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (14.404 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.161 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.404 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.161 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 45.677 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.029 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0046178 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.116 \text{ kipft}) + ((-0.029 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.018471 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.018471 \text{ kipft/ft})}{(-0.0046178 \text{ kip/ft})}$$

$$E = 4 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.018471 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.0046178 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.018471 \text{ kipft/ft})) + (4 \times (-0.0046178 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3472 \text{ ft}$$

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

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

$$V_{max} = ((-0.0046178 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.3472 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.3472 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.029727 \text{ kip}$$

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

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

$$M_{max} = ((-0.0046178 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(4 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.09911 \text{ kipft}$$

**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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.073 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.228 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.228 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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,

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

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

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

**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,

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

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

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

**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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.073\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0041392$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, $P = 11.073\ \mathrm{kip} \to 11073\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11073\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.96\ \mathrm{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.96\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.96\ \mathrm{kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

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

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

$$\phi V_n = (0.65) \times ((119.96\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.06\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 12.752\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.752\ \text{kip})}{(111.06\ \text{kip})}$$

$$Ratio = 0.11482$$

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

**Considering z-direction:**

$V_{max} = 0.029727\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.029727\ \text{kip})}{(111.06\ \text{kip})}$$

$$Ratio = 0.00026768$$

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),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 249.600kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2121.6 \text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$<br>$$\phi M_n = 249.6 \text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 45.677 \text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(45.677 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.183$$ | Status: **PASS**<br>Ratio: **0.180** |
| | **Considering z-direction:**<br>$M_{max} = 0.09911 \text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.09911 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.00039707$$ | Status: **PASS**<br>Ratio: **0.000** |

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

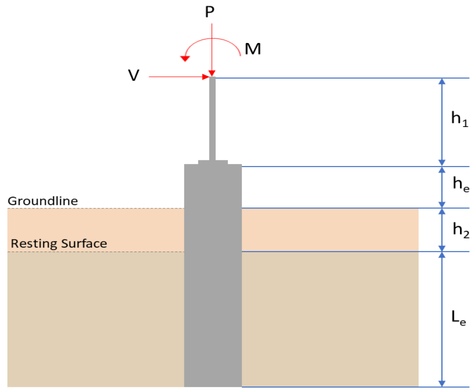
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.431 | 11.504 |
| $V_x$ (kip) | -3.045 | -5.080 |
| $V_z$ (kip) | 0.018 | 0.030 |
| $M_x$ (kipft) | 0.073 | 0.120 |
| $M_z$ (kipft) | 43.409 | 73.047 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-3.045\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.48487\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(43.409\ \mathrm{kipft}) + ((-3.045\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.9123\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.0358\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.018\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0028662\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.073\ \mathrm{kipft}) + ((0.018\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.011624\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.0347\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.0358\ \mathrm{ft}), (1.0347\ \mathrm{ft})]$$

$$L_{e,req} = 7.036\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.036\ \mathrm{ft})}{(7.5\ \mathrm{ft})}$$

$$Ratio = 0.93813$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.431\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.46444\ \mathrm{kip/ft}^2$$

$$q = 0.46444 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.46444 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.23222$$

Status: **PASS**
Ratio: **0.230**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.48487 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.9123 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.9123 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.48487 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (6.9123 \text{ kipft/ft})) + (4 \times (-0.48487 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1623 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.9123 \text{ kipft/ft})) + (3 \times (-0.48487 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.9123 \text{ kipft/ft})) + (2 \times (-0.48487 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.27749 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (6.9123 \text{ kipft/ft})) + ((-0.48487 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0867 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1623 \text{ ft})}{2}$$

$$p_a = 0.38717 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27749 \text{ kip/ft}^2)}{(0.38717 \text{ kip/ft}^2)}$$

$$Ratio = 0.71672$$

Status: **PASS**
Ratio: **0.720**

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

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0867\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96597$$

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

**Considering z-direction:**

$H_o = 0.0028662\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011624\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011624\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.011624\ \mathrm{kipft/ft})) + (4 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3451\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011624\ \mathrm{kipft/ft})) + (3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.011624\ \mathrm{kipft/ft})) + (2 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0021093\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.011624\ \mathrm{kipft/ft})) + ((0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.0047728\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3451\ \mathrm{ft})}{2}$$

$$p_a = 0.40088\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0021093\ \mathrm{kip/ft^2}\right)}{\left(0.40088\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0052616$$

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

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

$$p_s = R\,L_e$$

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

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

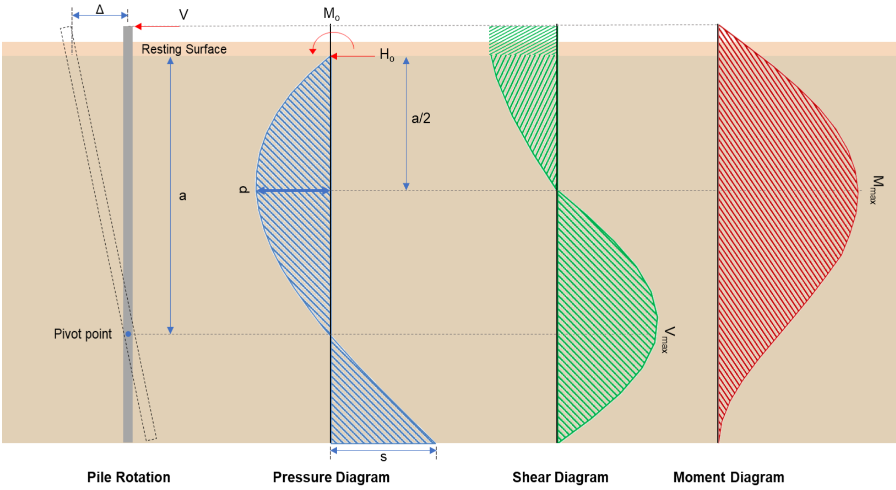
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0047728\ \text{kip/ft}^2)}{(1.125\ \text{kip/ft}^2)}$$

$$Ratio = 0.0042425$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-5.08\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.80892\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(73.047\ \text{kipft}) + ((-5.08\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 11.632\ \text{kipft/ft}$$

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

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

$$E = \frac{(11.632\ \text{kipft/ft})}{(-0.80892\ \text{kip/ft})}$$

$$E = 14.379\ \text{ft}$$

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

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

$$a = \frac{(4 \times (11.632\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.80892\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (11.632\ \text{kipft/ft})) + (4 \times (-0.80892\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1613\ \text{ft}$$

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

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

$$V_{max} = ((-0.80892\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1613\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1613\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.113\ \text{kip}$$

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

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

$$M_{max} = ((-0.80892\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(14.379\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.1613\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1613\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1613\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 46.966\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.03\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0047771\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.12\ \text{kipft}) + ((0.03\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.019108\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.019108\ \text{kipft/ft})}{(0.0047771\ \text{kip/ft})}$$

$$E = 4\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.019108\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (0.0047771\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.019108\ \text{kipft/ft})) + (4 \times (0.0047771\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.3472\ \text{ft}$$

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

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

$$V_{max} = ((0.0047771\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3472\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3472\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.030752\ \text{kip}$$

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

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

$$M_{max} = ((0.0047771\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(4\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.3472\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3472\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3472\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

| | | |
|---|---|---|
| | $M_{max} = 0.10253 \text{ kipft}$ | |

**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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.504 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.214 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.214 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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,

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

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

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

**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,

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

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

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

**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<br>$$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$<br>$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$<br>$$\phi P_N = 2675.2\ \mathrm{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(11.504\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$<br>$$Ratio = 0.0043003$$ | Status: **PASS**<br>Ratio: **0.000** |

| | | |
|---|---|---|
| | **Shear Strength (ACI 318-19, LRFD)**<br>**Parameters:**<br>$b_w = 48\ \mathrm{in}$ - Effective width, | |
| *22.5.2.2* | $d$ - Effective depth<br>$$d = 0.80\, D$$<br>$$d = 0.80 \times (48\ \mathrm{in})$$<br>$$d = 38.4\ \mathrm{in}$$ | |
| *22.5.5.1.3* | $\lambda_s$ - size effect modification factor<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$<br>$$\lambda_s = 0.64282$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, | |
| *22.5.5.1.1* | $V_{c,max}$ - Max shear strength of concrete<br>$$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$<br>$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,max} = 296.21\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, $P = 11.504\ \mathrm{kip} \to 11504\ \mathrm{lbf}$, | |
| *22.5.5.1.1(a)* | $V_{c,a}$ - Shear strength of concrete (a)<br>$$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$<br>$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11504\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,a} = 120.02\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \to 2500\ \mathrm{psi}$, | |
| *22.5.5.1.2* | $V_{c,b}$ - Shear strength of concrete (b)<br>$$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$<br>$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,b} = 348.89\ \mathrm{kip}$$<br>$V_c$ - Governing shear strength of concrete<br>$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$<br>$$V_c = Min\left[(296.21\ \mathrm{kip}), (120.02\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$<br>$$V_c = 120.02\ \mathrm{kip}$$ | |

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.02 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.09 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 13.113 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.113 \text{ kip})}{(111.09 \text{ kip})}$$

$$Ratio = 0.11803$$

Status: **PASS**
Ratio: **0.120**

**Considering z-direction:**

$V_{max} = 0.030752 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.030752 \text{ kip})}{(111.09 \text{ kip})}$$

$$Ratio = 0.00027681$$

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),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 249.600kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi \, 0.85 \, f'_{ck} \, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2121.6 \text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$<br>$$\phi M_n = 249.6 \text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 46.966 \text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(46.966 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.18817$$ | Status: **PASS**<br>Ratio: **0.190** |
| | **Considering z-direction:**<br>$M_{max} = 0.10253 \text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.10253 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.00041076$$ | Status: **PASS**<br>Ratio: **0.000** |

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

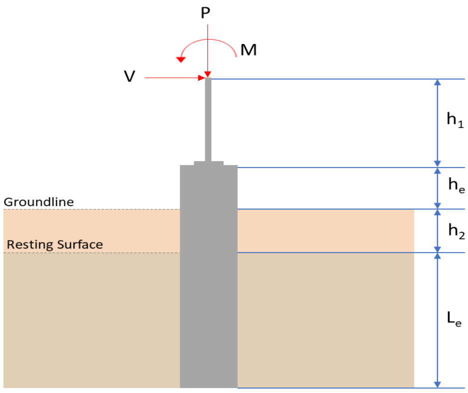
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 7.5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.431 | 11.504 |
| $V_x$ (kip) | -3.045 | -5.080 |
| $V_z$ (kip) | -0.018 | -0.030 |
| $M_x$ (kipft) | -0.073 | -0.120 |
| $M_z$ (kipft) | 43.409 | 73.047 |

**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,

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

$$H_o = \frac{(-3.045 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.48487 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(43.409 \text{ kipft}) + ((-3.045 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.9123 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.0358 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0028662 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.073 \text{ kipft}) + ((-0.018 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.011624 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.91722 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.0358 \text{ ft}), (0.91722 \text{ ft})]$$

$$L_{e,req} = 7.036 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.036 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.93813$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.431 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.46444 \text{ kip/ft}^2$$

$$q = 0.46444\ \mathrm{kip/ft^2}$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.46444\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.23222$$

Status: **PASS**
Ratio: **0.230**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.48487\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.9123\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.9123\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.48487\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (6.9123\ \mathrm{kipft/ft})) + (4 \times (-0.48487\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1623\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.9123\ \mathrm{kipft/ft})) + (3 \times (-0.48487\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (6.9123\ \mathrm{kipft/ft})) + (2 \times (-0.48487\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.27749\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (6.9123\ \mathrm{kipft/ft})) + ((-0.48487\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0867\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1623\ \mathrm{ft})}{2}$$

$$p_a = 0.38717\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27749\ \mathrm{kip/ft^2}\right)}{\left(0.38717\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71672$$

Status: **PASS**
Ratio: **0.720**

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

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0867\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96597$$

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

**Considering z-direction:**

$H_o = -0.0028662\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011624\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011624\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.011624\ \mathrm{kipft/ft})) + (4 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3451\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011624\ \mathrm{kipft/ft})) + (3 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.011624\ \mathrm{kipft/ft})) + (2 \times (-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = -0.00053158\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.011624\ \mathrm{kipft/ft})) + ((-0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.00018684\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3451\ \mathrm{ft})}{2}$$

$$p_a = 0.40088\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00053158\ \mathrm{kip/ft^2}\right)}{\left(0.40088\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.001326$$

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

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

$$p_s = R\,L_e$$

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

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

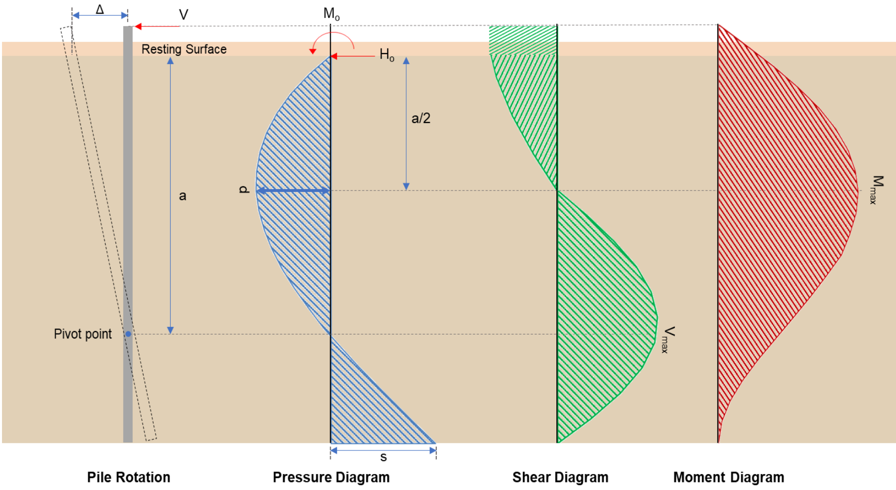
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00018684\ \text{kip/ft}^2)}{(1.125\ \text{kip/ft}^2)}$$

$$Ratio = 0.00016608$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-5.08\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.80892\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(73.047\ \text{kipft}) + ((-5.08\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 11.632\ \text{kipft/ft}$$

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

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

$$E = \frac{(11.632\ \text{kipft/ft})}{(-0.80892\ \text{kip/ft})}$$

$$E = 14.379\ \text{ft}$$

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

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

$$a = \frac{(4 \times (11.632\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.80892\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (11.632\ \text{kipft/ft})) + (4 \times (-0.80892\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1613\ \text{ft}$$

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

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

$$V_{max} = ((-0.80892\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.1613\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.379\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.1613\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.113\ \text{kip}$$

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

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

$$M_{max} = ((-0.80892 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[ \left( \frac{(14.379 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1613 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.379 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.1613 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (14.379 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.1613 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 46.966 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.03 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0047771 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.12 \text{ kipft}) + ((-0.03 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.019108 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.019108 \text{ kipft/ft})}{(-0.0047771 \text{ kip/ft})}$$

$$E = 4 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.019108 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.0047771 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.019108 \text{ kipft/ft})) + (4 \times (-0.0047771 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3472 \text{ ft}$$

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

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

$$V_{max} = ((-0.0047771 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.3472 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.3472 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.030752 \text{ kip}$$

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

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

$$M_{max} = ((-0.0047771 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[ \left( \frac{(4 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left( \frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left( \frac{(5.3472 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

| | | | |
|---|---|---|---|
| | $$M_{max} = 0.10253 \text{ kipft}$$ | | |

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.504 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.214 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.214 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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,

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

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

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

**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,

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**

| | | |
|---|---|---|
| | Ties: **#3(0.375 in) - 10 in** | |

| | | |
|---|---|---|
| 22.4.2.2 | **Axial Compression Strength (ACI 318-19, LRFD)**<br>$\phi P_N$ - Allowable axial compressive strength<br>$$\phi P_N = \phi\, 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$<br>$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$<br>$$\phi P_N = 2675.2\ \mathrm{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(11.504\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$<br>$$Ratio = 0.0043003$$ | Status: **PASS**<br>Ratio: **0.000** |

| | | |
|---|---|---|
| | **Shear Strength (ACI 318-19, LRFD)**<br>**Parameters:**<br>$b_w = 48\ \mathrm{in}$ - Effective width, | |
| 22.5.2.2 | $d$ - Effective depth<br>$$d = 0.80\ D$$<br>$$d = 0.80 \times (48\ \mathrm{in})$$<br>$$d = 38.4\ \mathrm{in}$$ | |
| 22.5.5.1.3 | $\lambda_s$ - size effect modification factor<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$<br>$$\lambda_s = 0.64282$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, | |
| 22.5.5.1.1 | $V_{c,max}$ - Max shear strength of concrete<br>$$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$<br>$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,max} = 296.21\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 11.504\ \mathrm{kip} \rightarrow 11504\ \mathrm{lbf}$, | |
| 22.5.5.1.1(a) | $V_{c,a}$ - Shear strength of concrete (a)<br>$$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$<br>$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11504\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,a} = 120.02\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, | |
| 22.5.5.1.2 | $V_{c,b}$ - Shear strength of concrete (b)<br>$$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$<br>$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,b} = 348.89\ \mathrm{kip}$$<br>$V_c$ - Governing shear strength of concrete<br>$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$<br>$$V_c = Min\left[(296.21\ \mathrm{kip}), (120.02\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$<br>$$V_c = 120.02\ \mathrm{kip}$$ | |

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.02\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.09\ \mathrm{kip}$$

**Considering x-direction:**

$V_{max} = 13.113\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.113\ \mathrm{kip})}{(111.09\ \mathrm{kip})}$$

$$Ratio = 0.11803$$

Status: **PASS**
Ratio: **0.120**

**Considering z-direction:**

$V_{max} = 0.030752\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.030752\ \mathrm{kip})}{(111.09\ \mathrm{kip})}$$

$$Ratio = 0.00027681$$

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

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

$S_m$ - Section modulus

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

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

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

| | | |
|---|---|---|
| | $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 249.600kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2121.6 \text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$<br>$$\phi M_n = 249.6 \text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 46.966 \text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(46.966 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.18817$$ | Status: **PASS**<br>Ratio: **0.190** |
| | **Considering z-direction:**<br>$M_{max} = 0.10253 \text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.10253 \text{ kipft})}{(249.6 \text{ kipft})}$$<br>$$Ratio = 0.00041076$$ | Status: **PASS**<br>Ratio: **0.000** |

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

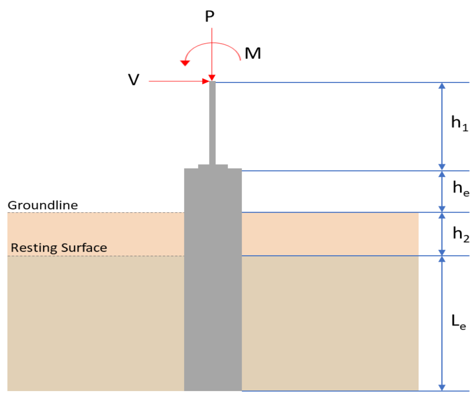
## SkyCiv Foundation Design

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
$L = 7.5\text{ ft}$ - Total pile length
$h_1 = 0\text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\text{ ft}$ - Depth to resisting surface
$h_e = 0\text{ ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 7.159 | 11.073 |
| $V_x$ (kip) | -2.961 | -4.933 |
| $V_z$ (kip) | 0.018 | 0.029 |
| $M_x$ (kipft) | 0.074 | 0.116 |
| $M_z$ (kipft) | 42.241 | 71.058 |

**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,

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

$$H_o = \frac{(-2.961\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.4715\text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(42.241\ \mathrm{kipft}) + ((-2.961\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.7263\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 6.9833\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.018\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0028662\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.074\ \mathrm{kipft}) + ((0.018\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.011783\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.0389\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.9833\ \mathrm{ft}), (1.0389\ \mathrm{ft})]$$

$$L_{e,req} = 6.983\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.983\ \mathrm{ft})}{(7.5\ \mathrm{ft})}$$

$$Ratio = 0.93107$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(7.159\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.44744\ \mathrm{kip/ft}^2$$

$q = 0.44744 \text{ kip/ft}$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.44744 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.22372$$

Status: **PASS**
Ratio: **0.220**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.4715 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.7263 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.7263 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.4715 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (6.7263 \text{ kipft/ft})) + (4 \times (-0.4715 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1622 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.7263 \text{ kipft/ft})) + (3 \times (-0.4715 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.7263 \text{ kipft/ft})) + (2 \times (-0.4715 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.27017 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (6.7263 \text{ kipft/ft})) + ((-0.4715 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0577 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1622 \text{ ft})}{2}$$

$$p_a = 0.38717 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27017 \text{ kip/ft}^2)}{(0.38717 \text{ kip/ft}^2)}$$

$$Ratio = 0.69782$$

Status: **PASS**
Ratio: **0.700**

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

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0577\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94021$$

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

**Considering z-direction:**

$H_o = 0.0028662\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011783\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011783\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.011783\ \mathrm{kipft/ft})) + (4 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.343\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011783\ \mathrm{kipft/ft})) + (3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\ 2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.011783\ \mathrm{kipft/ft})) + (2 \times (0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.0021206\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.011783\ \mathrm{kipft/ft})) + ((0.0028662\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.0048068\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.343\ \mathrm{ft})}{2}$$

$$p_a = 0.40072\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0021206\ \mathrm{kip/ft^2}\right)}{\left(0.40072\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0052918$$

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

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

$$p_s = R\,L_e$$

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

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

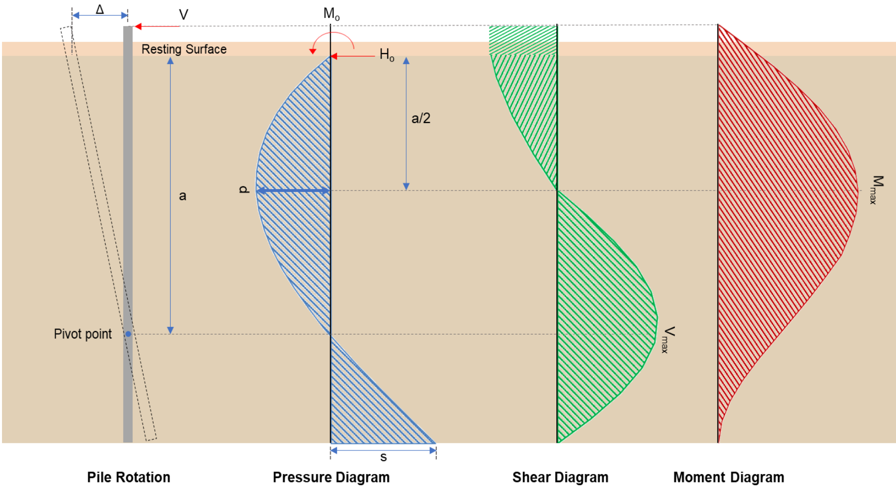
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0048068\ \mathrm{kip/ft^2})}{(1.125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0042727$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.933\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.78551\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(71.058\ \mathrm{kipft}) + ((-4.933\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 11.315\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(11.315\ \mathrm{kipft/ft})}{(-0.78551\ \mathrm{kip/ft})}$$

$$E = 14.405\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (11.315\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.78551\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (11.315\ \mathrm{kipft/ft})) + (4 \times (-0.78551\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.161\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.78551\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.405\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.161\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.405\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.161\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.752\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.78551\text{ kip/ft}) \times (48\text{ in}) \times (7.5\text{ ft})) \times \left[\left(\frac{(14.405\text{ ft})}{(7.5\text{ ft})} + \frac{(5.161\text{ ft})}{2 \times (7.5\text{ ft})}\right) - \left[\left(\frac{4 \times (14.405\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.161\text{ ft})}{2 \times (7.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.405\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.161\text{ ft})}{2 \times (7.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 45.678\text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.029\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0046178\text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.116\text{ kipft}) + ((0.029\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.018471\text{ kipft/ft}$$

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

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

$$E = \frac{(0.018471\text{ kipft/ft})}{(0.0046178\text{ kip/ft})}$$

$$E = 4\text{ ft}$$

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

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

$$a = \frac{(4 \times (0.018471\text{ kipft/ft}) \times (7.5\text{ ft})) + \left(3 \times (0.0046178\text{ kip/ft}) \times (7.5\text{ ft})^2\right)}{(6 \times (0.018471\text{ kipft/ft})) + (4 \times (0.0046178\text{ kip/ft}) \times (7.5\text{ ft}))}$$

$$a = 5.3472\text{ ft}$$

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

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

$$V_{max} = ((0.0046178\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.3472\text{ ft})}{(7.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.3472\text{ ft})}{(7.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.029727\text{ kip}$$

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

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

$$M_{max} = ((0.0046178\text{ kip/ft}) \times (48\text{ in}) \times (7.5\text{ ft})) \times \left[\left(\frac{(4\text{ ft})}{(7.5\text{ ft})} + \frac{(5.3472\text{ ft})}{2 \times (7.5\text{ ft})}\right) - \left[\left(\frac{4 \times (4\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.3472\text{ ft})}{2 \times (7.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.3472\text{ ft})}{2 \times (7.5\text{ ft})}\right)^4\right]\right]$$

| | | | |
|---|---|---|---|
| | $M_{max} = 0.09911 \text{ kipft}$ | | |

**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* $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.073 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.228 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-84.228 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

$n_{rebar}$ - 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,

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

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

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

**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,

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

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

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

**Summary:**

Main reinforcement: **14 - #5 (0.625 in)**

| | | |
|---|---|---|
| | Ties: **#3(0.375 in) - 10 in** | |
| 22.4.2.2 | **Axial Compression Strength (ACI 318-19, LRFD)**<br>$\phi P_N$ - Allowable axial compressive strength<br>$$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$<br>$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$<br>$$\phi P_N = 2675.2\ \mathrm{kip}$$<br>$Ratio$ - Capacity<br>$$Ratio = \frac{P}{\phi P_N}$$<br>$$Ratio = \frac{(11.073\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$<br>$$Ratio = 0.0041392$$ | Status: **PASS**<br>Ratio: **0.000** |
| 22.5.2.2<br>22.5.5.1.3<br>22.5.5.1.1<br>22.5.5.1.1(a)<br>22.5.5.1.2 | **Shear Strength (ACI 318-19, LRFD)**<br>**Parameters:**<br>$b_w = 48\ \mathrm{in}$ - Effective width,<br>$d$ - Effective depth<br>$$d = 0.80\ D$$<br>$$d = 0.80 \times (48\ \mathrm{in})$$<br>$$d = 38.4\ \mathrm{in}$$<br>$\lambda_s$ - size effect modification factor<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$<br>$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$<br>$$\lambda_s = 0.64282$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$ ,<br>$V_{c,max}$ - Max shear strength of concrete<br>$$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$<br>$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,max} = 296.21\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$ ,$P = 11.073\ \mathrm{kip} \rightarrow 11073\ \mathrm{lbf}$ ,<br>$V_{c,a}$ - Shear strength of concrete (a)<br>$$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$<br>$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11073\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,a} = 119.96\ \mathrm{kip}$$<br>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$ ,<br>$V_{c,b}$ - Shear strength of concrete (b)<br>$$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$<br>$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{c,b} = 348.89\ \mathrm{kip}$$<br>$V_c$ - Governing shear strength of concrete<br>$$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$<br>$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.96\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$<br>$$V_c = 119.96\ \mathrm{kip}$$ | |

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.96\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.06\ \mathrm{kip}$$

**Considering x-direction:**

$V_{max} = 12.752\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.752\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.11483$$

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

**Considering z-direction:**

$V_{max} = 0.029727\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.029727\ \mathrm{kip})}{(111.06\ \mathrm{kip})}$$

$$Ratio = 0.00026768$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

*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:**

$M_{max} = 45.678 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(45.678 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.183$$

Status: **PASS**
Ratio: **0.180**

**Considering z-direction:**

$M_{max} = 0.09911 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.09911 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00039707$$

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