# Your Project Calculations

Project Name: Bozeman Trail RV Park RevC

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Bozeman%20Trail%20RV%20Park%20RevC&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=whPppjNygTWE1ImtKcAHkA3ftxLFAwB8uWiZDxJlTYnu5CbkGN74rUKfsVaPy5GS

## Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 5P-19.75-6TOP-XD-45-L-5Hx13W-J7BL |
| **Duty Classification:** | XD |
| **Module Width:** | 41.10 in |
| **Module Length:** | 87.20in |
| **Number of Rows:** | 5 |
| **Number of Columns:** | 13 |
| **Total Number of Modules:** | 65 |
| **Desired Tilt Angle:** | 10 |
| **Front Edge Clearance:** | 14 |
| **Total Array Height at Tilt:** | 16.99 ft |
| **Total Frame Length:** | 94.00 ft |
| **Frame Weight:** | 5090 lbs |
| **Array Dimensions N/S:** | 17.33 ft |
| **Array Dimensions E/W:** | 95.55 ft |
| **Rail Length:** | 208.00 in |
| **Rail Spacing:** | 3.63 ft |
| **Rail Check:** | |

## Support Specifications

| | |
|---|---|
| **Pole Size:** | 6in Pipe Sch 40 |
| **Pole Length above Grade:** | 15.50 ft |
| **Number of Poles:** | 5 |
| **Pole Spacing:** | 19.75 ft |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Round |
| **Foundation Dimensions:** | Ø36 in |
| **Foundation Depth (below grade):** | Pile 1: 6.75 ft<br>Pile 2: 7.00 ft<br>Pile 3: 7.00 ft<br>Pile 4: 7.00 ft<br>Pile 5: 6.75 ft |
| **Foundation Volume:** | 9.032 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.036122 kip |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | B |
| **Soil Classification:** | sand |
| **Site Location:** | 31842 Frontage Rd, Bozeman, MT 59715, USA |
| **Wind Speed:** | 100 mph |
| **Snow Load:** | 40 psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.024192 ksf |


### Design Disclaimer

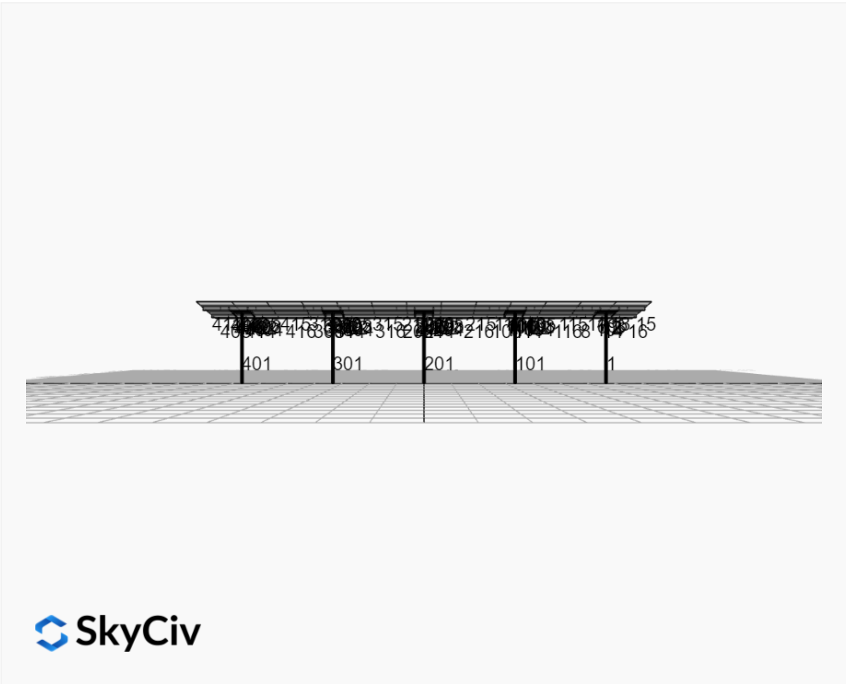
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

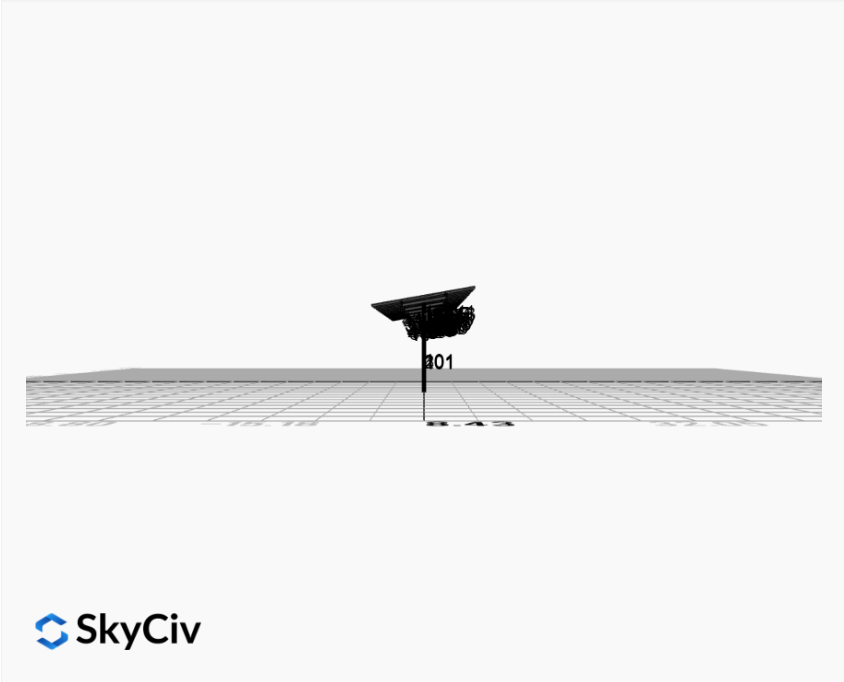
### AutoDesigner Input

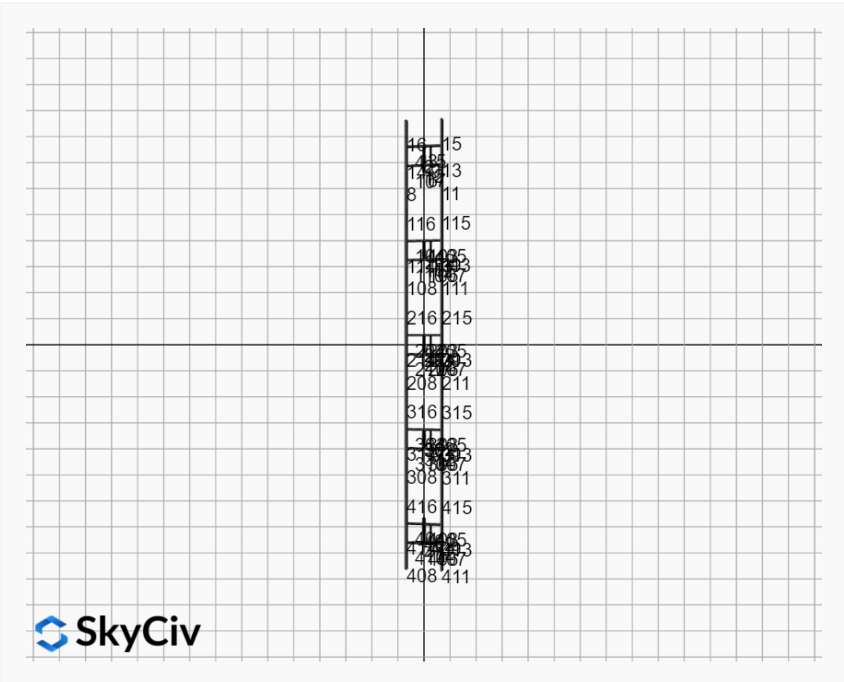
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"Bozeman Trail RV Park RevC","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_width":41.1,"module_length":87.2,"number_rows":"5","number_columns":13,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":10,"ground_clearance":14,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","foundation_type":"Round","foundation_size":36,"check_rails":true}

**Design Notes:**

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




SkyCiv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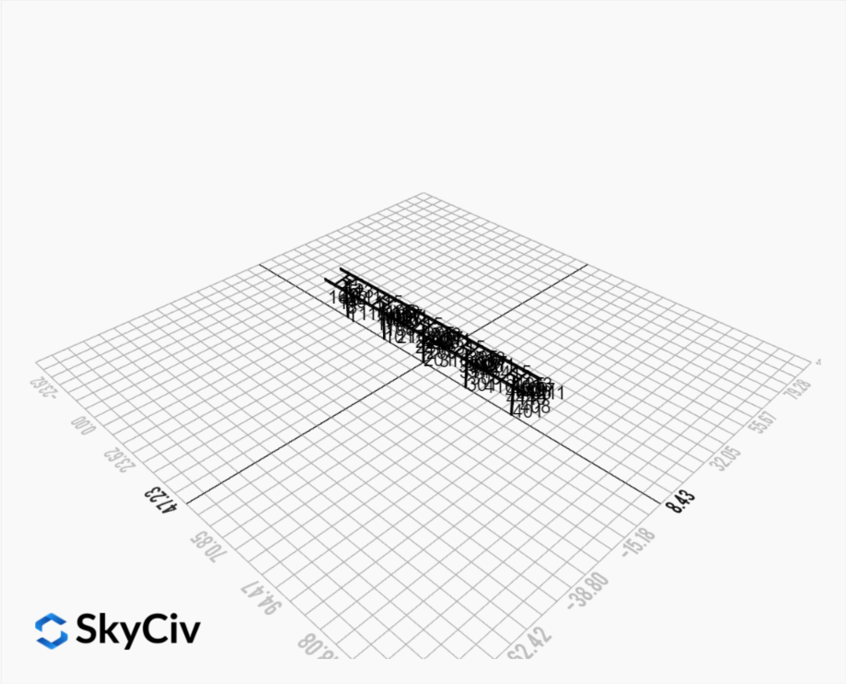
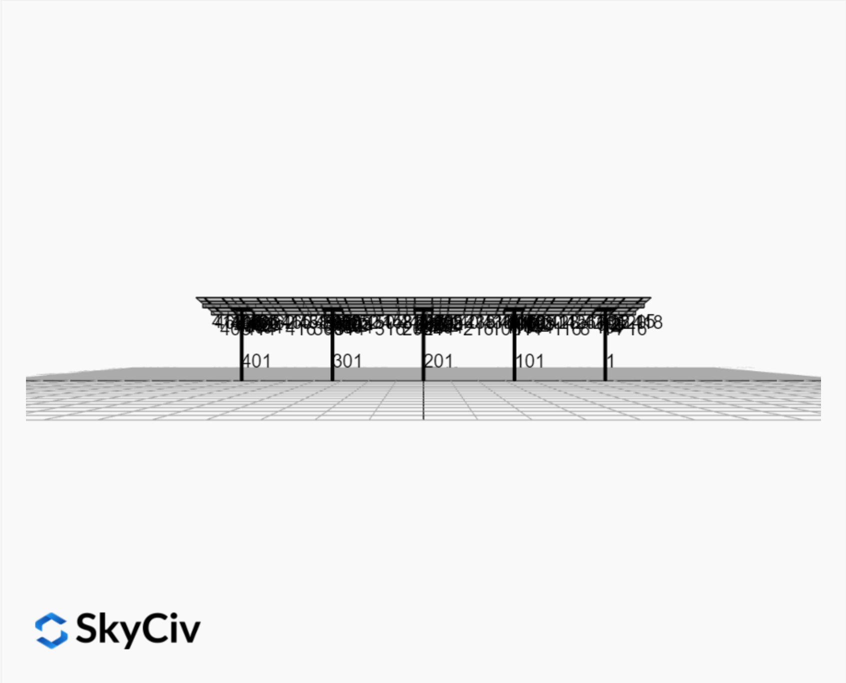
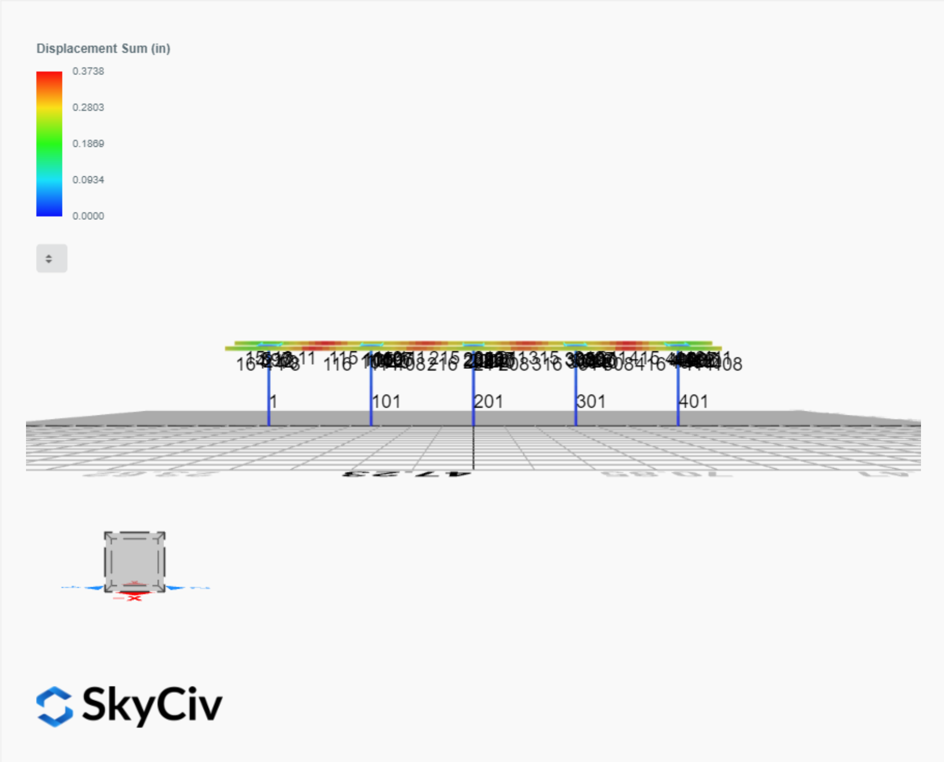
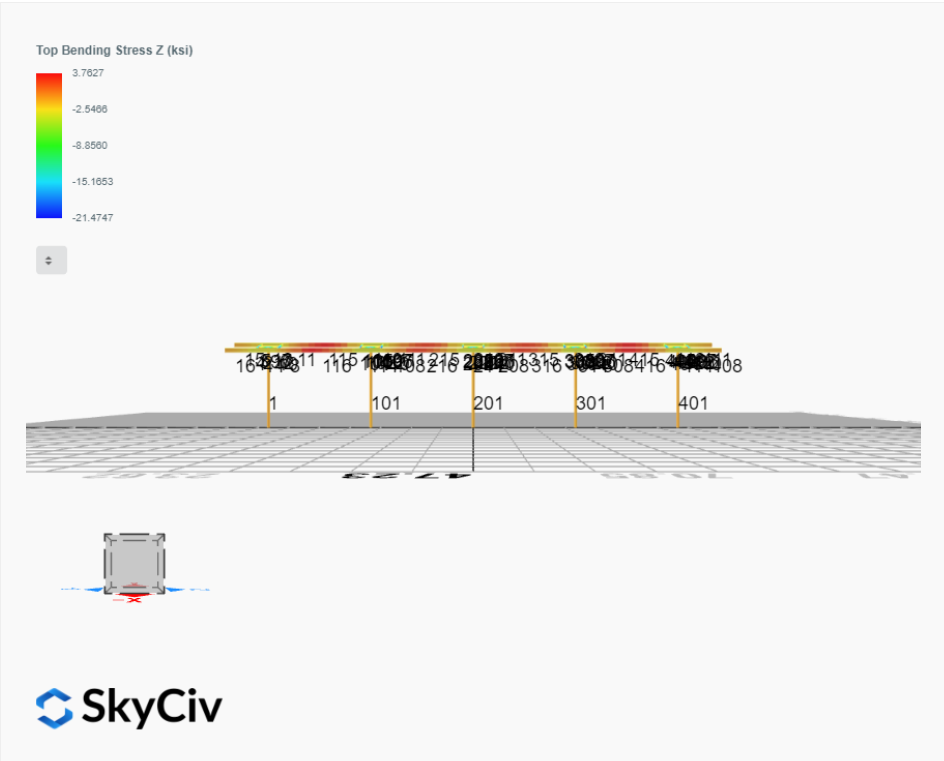
SkyCiv

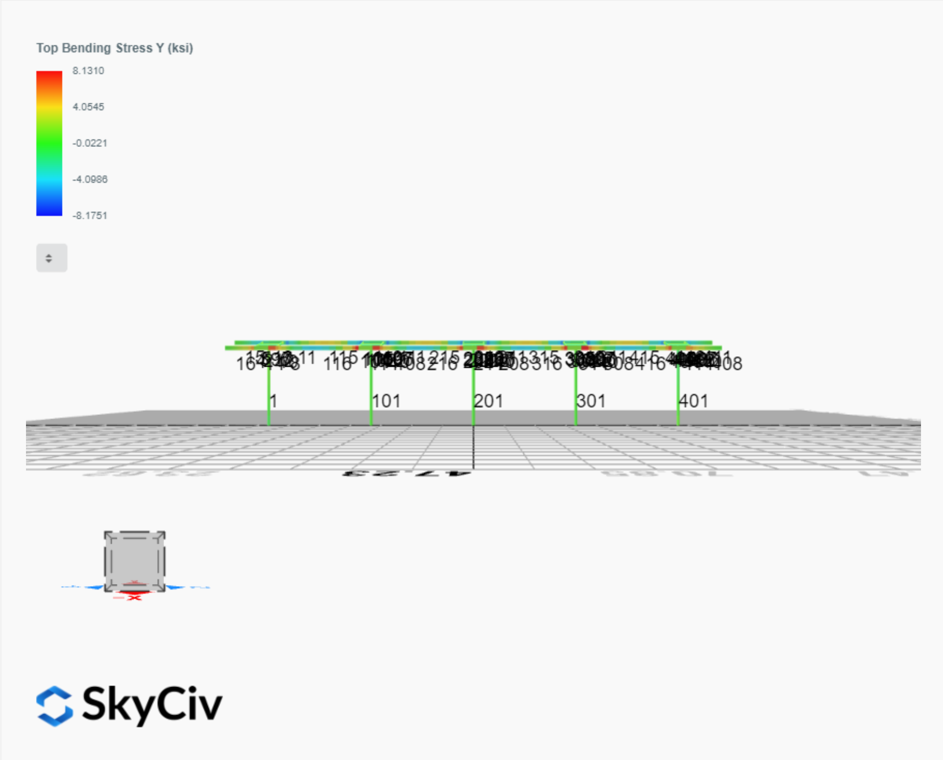


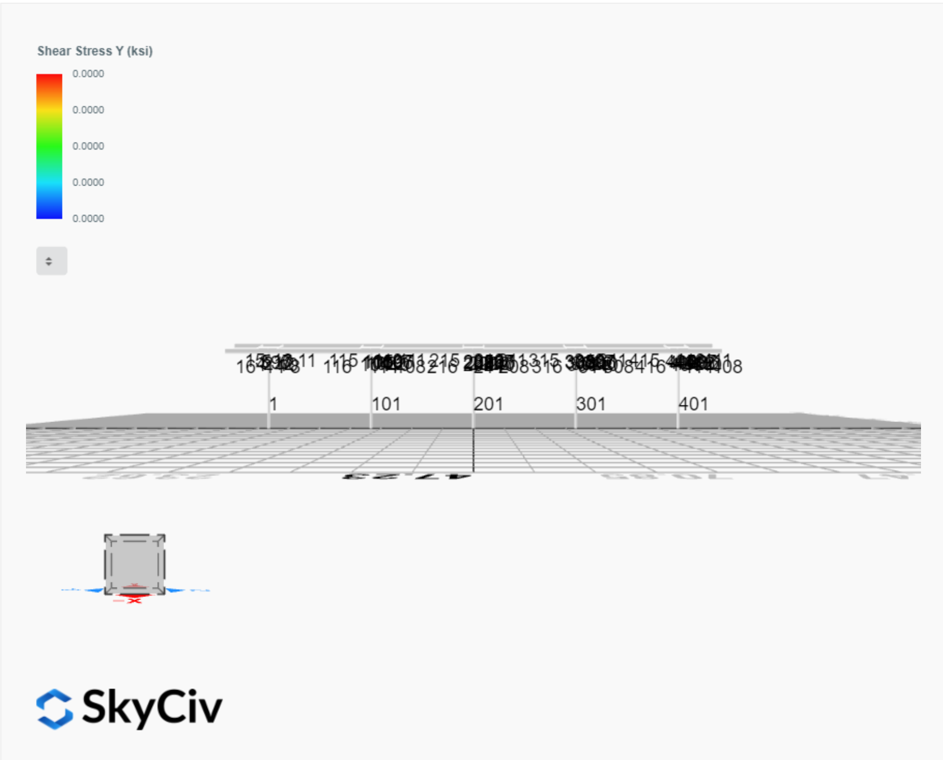

401
301
201
101
1

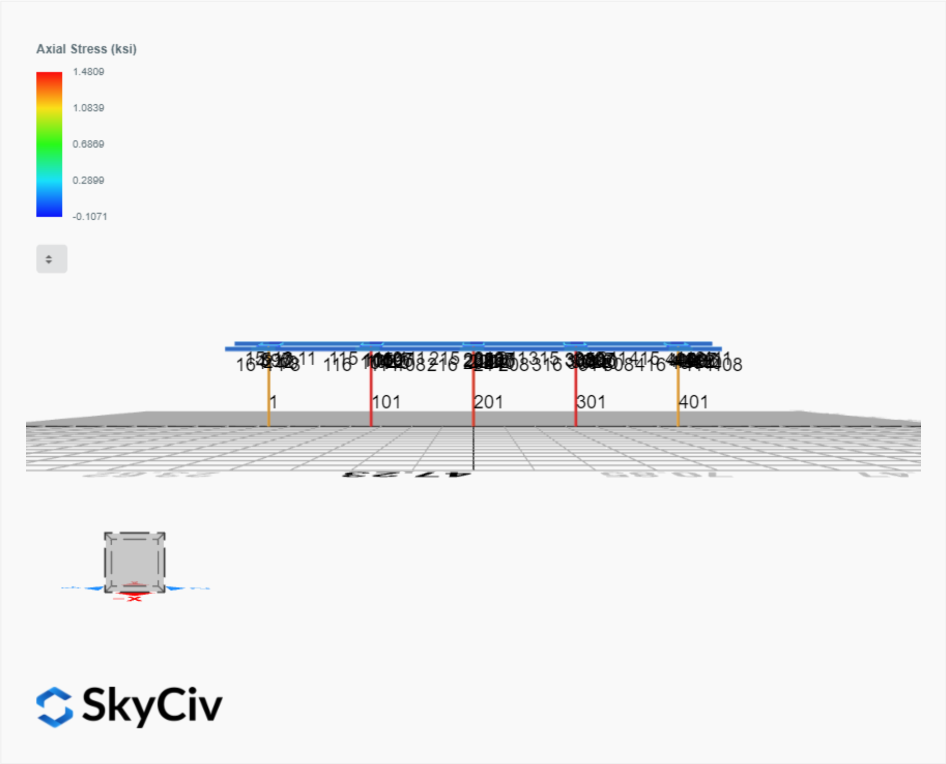
## FEM Results (Envelope Worst Case for each member)




Top Bending Stress Y (ksi)
8.1310
4.0545
-0.0221
-4.0986
-8.1751
1
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
1
101
201
301
401
SkyCiv



Axial Stress (ksi)
1.4809
1.0839
0.6869
0.2899
-0.1071
1
101
201
301
401
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 | 0.0026 | 2.3269 | 0.0133 | 0.0679 | -0.0015 | -0.0007 |
| ULS: 2. D + L | 0.0026 | 2.3269 | 0.0133 | 0.0679 | -0.0015 | -0.0007 |
| ULS: 3. D + (S or Lr or R) | 0.0126 | 9.3987 | 0.0674 | 0.3459 | -0.0079 | -0.1184 |
| ULS: 3. D + (S or Lr or R) | 0.0026 | 2.3269 | 0.0133 | 0.0679 | -0.0015 | -0.0007 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0101 | 7.6307 | 0.0539 | 0.2764 | -0.0063 | -0.0889 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0026 | 2.3269 | 0.0133 | 0.0679 | -0.0015 | -0.0007 |
| ULS: 5b. D + 0.7E | 0.0026 | 2.3269 | 0.0133 | 0.0679 | -0.0015 | -0.0007 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0101 | 7.6307 | 0.0539 | 0.2764 | -0.0063 | -0.0889 |
| ULS: 8. 0.6D + 0.7E | 0.0015 | 1.3961 | 0.0080 | 0.0408 | -0.0009 | -0.0004 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.3818 | 4.3927 | 0.0340 | 0.1730 | -0.0184 | 8.0199 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.3818 | 4.3927 | 0.0340 | 0.1730 | -0.0184 | 8.0199 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.2635 | 0.8800 | 0.0012 | 0.0068 | 0.0067 | -2.7477 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.2463 | 1.0642 | -0.0017 | -0.0078 | 0.0126 | -8.4085 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.2782 | 9.1801 | 0.0694 | 0.3552 | -0.0189 | 5.9265 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.2782 | 9.1801 | 0.0694 | 0.3552 | -0.0189 | 5.9265 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2058 | 6.5456 | 0.0448 | 0.2306 | -0.0001 | -2.1492 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1929 | 6.6837 | 0.0426 | 0.2196 | 0.0043 | -6.3948 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.2857 | 3.8763 | 0.0289 | 0.1468 | -0.0141 | 6.0148 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.2857 | 3.8763 | 0.0289 | 0.1468 | -0.0141 | 6.0148 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.1982 | 1.2418 | 0.0042 | 0.0221 | 0.0047 | -2.0610 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1854 | 1.3799 | 0.0020 | 0.0112 | 0.0091 | -6.3065 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.3828 | 3.4620 | 0.0287 | 0.1459 | -0.0178 | 8.0202 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.3828 | 3.4620 | 0.0287 | 0.1459 | -0.0178 | 8.0202 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.2624 | -0.0507 | -0.0041 | -0.0204 | 0.0073 | -2.7475 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.2453 | 0.1334 | -0.0071 | -0.0350 | 0.0132 | -8.4082 |

### 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 | 15.8304 |
| Shear X | -0.6406 |
| Shear Z | 0.1225 |
| Moment X | 0.6364 |
| Moment Y (Twist) | 0.0361 |
| Moment Z | 15.9606 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 9.3987 |
| Shear X | -0.3828 |
| Shear Z | 0.0694 |
| Moment X | 0.3552 |
| Moment Y (Twist) | 0.0189 |
| Moment Z | 8.4085 |

## 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 | -0.0025 | 2.6238 | -0.0011 | -0.0056 | 0.0003 | 0.0624 |
| ULS: 2. D + L | -0.0025 | 2.6238 | -0.0011 | -0.0056 | 0.0003 | 0.0624 |
| ULS: 3. D + (S or Lr or R) | -0.0122 | 10.8894 | -0.0055 | -0.0285 | 0.0012 | 0.2101 |
| ULS: 3. D + (S or Lr or R) | -0.0025 | 2.6238 | -0.0011 | -0.0056 | 0.0003 | 0.0624 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0098 | 8.8230 | -0.0044 | -0.0228 | 0.0010 | 0.1732 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0025 | 2.6238 | -0.0011 | -0.0056 | 0.0003 | 0.0624 |
| ULS: 5b. D + 0.7E | -0.0025 | 2.6238 | -0.0011 | -0.0056 | 0.0003 | 0.0624 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0098 | 8.8230 | -0.0044 | -0.0228 | 0.0010 | 0.1732 |
| ULS: 8. 0.6D + 0.7E | -0.0015 | 1.5743 | -0.0007 | -0.0034 | 0.0002 | 0.0375 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.4111 | 5.0293 | 0.0008 | 0.0036 | -0.0071 | 8.6293 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.4111 | 5.0293 | 0.0008 | 0.0036 | -0.0071 | 8.6293 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.2901 | 0.9344 | -0.0008 | -0.0039 | 0.0017 | -2.9589 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.2410 | 1.1575 | -0.0039 | -0.0192 | 0.0087 | -8.7504 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.3163 | 10.6272 | -0.0030 | -0.0159 | -0.0046 | 6.5983 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3163 | 10.6272 | -0.0030 | -0.0159 | -0.0046 | 6.5983 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2096 | 7.5560 | -0.0042 | -0.0215 | 0.0020 | -2.0929 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1728 | 7.7233 | -0.0065 | -0.0330 | 0.0073 | -6.4365 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.3090 | 4.4280 | 0.0003 | 0.0013 | -0.0053 | 6.4876 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3090 | 4.4280 | 0.0003 | 0.0013 | -0.0053 | 6.4876 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2169 | 1.3567 | -0.0009 | -0.0043 | 0.0013 | -2.2036 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1801 | 1.5241 | -0.0032 | -0.0158 | 0.0066 | -6.5472 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.4101 | 3.9798 | 0.0012 | 0.0059 | -0.0072 | 8.6043 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.4101 | 3.9798 | 0.0012 | 0.0059 | -0.0072 | 8.6043 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.2911 | -0.1151 | -0.0003 | -0.0017 | 0.0016 | -2.9839 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.2420 | 0.1080 | -0.0034 | -0.0170 | 0.0086 | -8.7754 |

### 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 | 18.3751 |
| Shear X | -0.6834 |
| Shear Z | -0.0125 |
| Moment X | -0.0648 |
| Moment Y (Twist) | 0.0178 |
| Moment Z | 16.5691 |

### 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 | 10.8894 |
| Shear X | -0.4111 |
| Shear Z | -0.0065 |
| Moment X | -0.0330 |
| Moment Y (Twist) | 0.0087 |
| Moment Z | 8.7754 |

## 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 | -0.0002 | 2.5936 | -0.0000 | 0.0000 | 0.0000 | 0.0432 |
| ULS: 2. D + L | -0.0002 | 2.5936 | -0.0000 | 0.0000 | 0.0000 | 0.0432 |
| ULS: 3. D + (S or Lr or R) | -0.0008 | 10.7368 | 0.0000 | -0.0000 | 0.0000 | 0.1141 |
| ULS: 3. D + (S or Lr or R) | -0.0002 | 2.5936 | -0.0000 | 0.0000 | 0.0000 | 0.0432 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0006 | 8.7010 | 0.0000 | -0.0000 | 0.0000 | 0.0964 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0002 | 2.5936 | -0.0000 | 0.0000 | 0.0000 | 0.0432 |
| ULS: 5b. D + 0.7E | -0.0002 | 2.5936 | -0.0000 | 0.0000 | 0.0000 | 0.0432 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0006 | 8.7010 | 0.0000 | -0.0000 | 0.0000 | 0.0964 |
| ULS: 8. 0.6D + 0.7E | -0.0001 | 1.5562 | -0.0000 | 0.0000 | 0.0000 | 0.0259 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.4105 | 4.9727 | -0.0000 | 0.0000 | 0.0000 | 8.7110 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.4105 | 4.9727 | -0.0000 | 0.0000 | 0.0000 | 8.7110 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.2929 | 0.9262 | -0.0000 | 0.0000 | 0.0000 | -2.9905 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.2439 | 1.1409 | -0.0000 | 0.0000 | 0.0000 | -8.8928 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.3083 | 10.4853 | 0.0000 | -0.0000 | 0.0000 | 6.5973 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3083 | 10.4853 | 0.0000 | -0.0000 | 0.0000 | 6.5973 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2192 | 7.4504 | 0.0000 | -0.0000 | 0.0000 | -2.1788 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1825 | 7.6115 | -0.0000 | -0.0000 | 0.0000 | -6.6056 |

| 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 | -0.3079 | 4.3779 | -0.0000 | 0.0000 | 0.0000 | 6.5440 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3079 | 4.3779 | -0.0000 | 0.0000 | 0.0000 | 6.5440 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2197 | 1.3430 | -0.0000 | 0.0000 | 0.0000 | -2.2320 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1829 | 1.5041 | -0.0000 | 0.0000 | 0.0000 | -6.6588 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.4104 | 3.9352 | -0.0000 | 0.0000 | 0.0000 | 8.6937 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.4104 | 3.9352 | -0.0000 | 0.0000 | 0.0000 | 8.6937 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.2930 | -0.1113 | -0.0000 | 0.0000 | 0.0000 | -3.0077 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.2440 | 0.1035 | -0.0000 | 0.0000 | 0.0000 | -8.9101 |

### 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 | 18.1266 |
| Shear X | -0.6839 |
| Shear Z | -0.0000 |
| Moment X | 0.0001 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 16.8851 |

### 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 | 10.7368 |
| Shear X | -0.4105 |
| Shear Z | -0.0000 |
| Moment X | -0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 8.9101 |

## 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 | -0.0025 | 2.6238 | 0.0011 | 0.0056 | -0.0003 | 0.0624 |
| ULS: 2. D + L | -0.0025 | 2.6238 | 0.0011 | 0.0056 | -0.0003 | 0.0624 |
| ULS: 3. D + (S or Lr or R) | -0.0122 | 10.8894 | 0.0055 | 0.0285 | -0.0012 | 0.2101 |
| ULS: 3. D + (S or Lr or R) | -0.0025 | 2.6238 | 0.0011 | 0.0056 | -0.0003 | 0.0624 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0098 | 8.8230 | 0.0044 | 0.0228 | -0.0009 | 0.1732 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0025 | 2.6238 | 0.0011 | 0.0056 | -0.0003 | 0.0624 |
| ULS: 5b. D + 0.7E | -0.0025 | 2.6238 | 0.0011 | 0.0056 | -0.0003 | 0.0624 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0098 | 8.8230 | 0.0044 | 0.0228 | -0.0009 | 0.1732 |
| ULS: 8. 0.6D + 0.7E | -0.0015 | 1.5743 | 0.0007 | 0.0034 | -0.0002 | 0.0375 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.4111 | 5.0293 | -0.0008 | -0.0036 | 0.0071 | 8.6293 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.4111 | 5.0293 | -0.0008 | -0.0036 | 0.0071 | 8.6293 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.2901 | 0.9344 | 0.0008 | 0.0039 | -0.0017 | -2.9589 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.2410 | 1.1575 | 0.0039 | 0.0192 | -0.0087 | -8.7504 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.3163 | 10.6272 | 0.0030 | 0.0159 | 0.0046 | 6.5983 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3163 | 10.6272 | 0.0030 | 0.0159 | 0.0046 | 6.5983 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2096 | 7.5560 | 0.0042 | 0.0215 | -0.0020 | -2.0929 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1728 | 7.7233 | 0.0065 | 0.0330 | -0.0073 | -6.4365 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.3090 | 4.4280 | -0.0003 | -0.0013 | 0.0053 | 6.4876 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.3090 | 4.4280 | -0.0003 | -0.0013 | 0.0053 | 6.4876 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2169 | 1.3567 | 0.0009 | 0.0043 | -0.0013 | -2.2036 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1801 | 1.5241 | 0.0032 | 0.0158 | -0.0066 | -6.5472 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.4101 | 3.9798 | -0.0012 | -0.0059 | 0.0072 | 8.6043 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.4101 | 3.9798 | -0.0012 | -0.0059 | 0.0072 | 8.6043 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.2911 | -0.1151 | 0.0003 | 0.0017 | -0.0016 | -2.9839 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.2420 | 0.1080 | 0.0034 | 0.0170 | -0.0086 | -8.7754 |

### 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 | 18.3751 |
| Shear X | -0.6834 |
| Shear Z | 0.0125 |
| Moment X | 0.0649 |
| Moment Y (Twist) | 0.0177 |
| Moment Z | 16.5692 |

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 | 10.8894 |
| Shear X | -0.4111 |
| Shear Z | 0.0065 |
| Moment X | 0.0330 |
| Moment Y (Twist) | 0.0087 |
| Moment Z | 8.7754 |

## Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

### ASD Load Combination Results

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 1. D | 0.0026 | 2.3269 | -0.0133 | -0.0679 | 0.0015 | -0.0007 |
| ULS: 2. D + L | 0.0026 | 2.3269 | -0.0133 | -0.0679 | 0.0015 | -0.0007 |
| ULS: 3. D + (S or Lr or R) | 0.0126 | 9.3987 | -0.0674 | -0.3459 | 0.0079 | -0.1183 |
| ULS: 3. D + (S or Lr or R) | 0.0026 | 2.3269 | -0.0133 | -0.0679 | 0.0015 | -0.0007 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0101 | 7.6307 | -0.0539 | -0.2764 | 0.0063 | -0.0889 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0026 | 2.3269 | -0.0133 | -0.0679 | 0.0015 | -0.0007 |
| ULS: 5b. D + 0.7E | 0.0026 | 2.3269 | -0.0133 | -0.0679 | 0.0015 | -0.0007 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0101 | 7.6307 | -0.0539 | -0.2764 | 0.0063 | -0.0889 |
| ULS: 8. 0.6D + 0.7E | 0.0015 | 1.3961 | -0.0080 | -0.0408 | 0.0009 | -0.0004 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.3818 | 4.3927 | -0.0340 | -0.1730 | 0.0184 | 8.0199 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.3818 | 4.3927 | -0.0340 | -0.1730 | 0.0184 | 8.0199 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.2635 | 0.8800 | -0.0012 | -0.0068 | -0.0067 | -2.7477 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.2463 | 1.0642 | 0.0017 | 0.0078 | -0.0126 | -8.4085 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.2782 | 9.1801 | -0.0694 | -0.3552 | 0.0189 | 5.9265 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.2782 | 9.1801 | -0.0694 | -0.3552 | 0.0189 | 5.9265 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.2058 | 6.5456 | -0.0448 | -0.2306 | 0.0001 | -2.1492 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1929 | 6.6837 | -0.0426 | -0.2196 | -0.0043 | -6.3948 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.2857 | 3.8763 | -0.0289 | -0.1468 | 0.0141 | 6.0148 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.2857 | 3.8763 | -0.0289 | -0.1468 | 0.0141 | 6.0148 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.1982 | 1.2418 | -0.0042 | -0.0221 | -0.0047 | -2.0610 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.1854 | 1.3799 | -0.0020 | -0.0112 | -0.0091 | -6.3065 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.3828 | 3.4620 | -0.0287 | -0.1459 | 0.0178 | 8.0202 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.3828 | 3.4620 | -0.0287 | -0.1459 | 0.0178 | 8.0202 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.2624 | -0.0507 | 0.0041 | 0.0204 | -0.0073 | -2.7475 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.2453 | 0.1334 | 0.0071 | 0.0350 | -0.0132 | -8.4082 |

### 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 | 15.8304 |
| Shear X | -0.6406 |
| Shear Z | -0.1225 |
| Moment X | -0.6363 |
| Moment Y (Twist) | 0.0361 |
| Moment Z | 15.9609 |

### Worst Case Reactions ASD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 9.3987 |
| Shear X | -0.3828 |
| Shear Z | -0.0694 |
| Moment X | -0.3552 |
| Moment Y (Twist) | 0.0189 |
| Moment Z | 8.4085 |

## Project Details

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

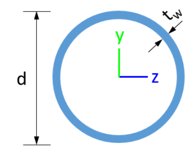
User Name: sales@mtsolar.us
Unit System: imperial

## Design Input Information

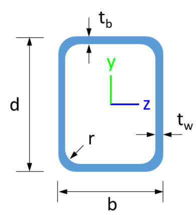
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

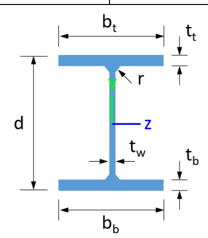
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 2in Pipe Sch 120 | 2.38 | 0.25 | | | | | |
| 6 | 4in Pipe Sch 120 | 4.50 | 0.44 | | | | | |
| 7 | 6in Pipe Sch 40 | 6.63 | 0.28 | | | | | |




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




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

| Section Properties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ID | Name | A ($in^2$) | J ($in^4$) | $I_{yp}$ ($in^4$) | $I_{zp}$ ($in^4$) | $I_w$ ($in^6$) | $S_{yp}$ ($in^3$) | $S_{zp}$ ($in^3$) |
| 3 | 2in Pipe Sch 120 | 1.67 | 1.91 | 0.96 | 0.96 | 0.00 | 1.13 | 1.13 |
| 6 | 4in Pipe Sch 120 | 5.58 | 23.29 | 11.64 | 11.64 | 0.00 | 7.24 | 7.24 |
| 7 | 6in Pipe Sch 40 | 5.58 | 56.28 | 28.14 | 28.14 | 0.00 | 11.28 | 11.28 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 17 | HSS5x3x1/4 | 3.37 | 11.00 | 4.81 | 10.70 | 62.42 | 3.77 | 5.38 |
| 20 | W10x12 | 3.54 | 0.05 | 2.18 | 53.80 | 50.90 | 1.74 | 12.60 |

| **Member Properties** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 7 | 32.56 | 32.56 | 15.51 | - | 300 | 200 | 1 |
| 2 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.20,1.18,1.18,1.26,1.16,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.72,1.18,1.18,1.10,1.17 | 300 | 200 | 1 |
| 4 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.69,1.68,1.68,1.68,1.61,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.74,1.69,1.68,1.68,1.64,1.69 | 300 | 200 | 1 |
| 5 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.69,1.67,1.67,1.80,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.61,1.67,1.67,1.59,1.66 | 300 | 200 | 1 |
| 6 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.27,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.16,1.18,1.18,1.12,1.17 | 300 | 200 | 1 |
| 7 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.69,1.67,1.67,1.80,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.40,1.67,1.67,1.60,1.66 | 300 | 200 | 1 |
| 8 | 20 | 1.33 | 1.33 | 2.05 | 1.60,1.60,1.60,1.60,1.60,1.60,1.56,1.56,1.58,1.75,1.54,1.54,1.69,2.06,1.59,1.59,1.60,1.63,1.56,1.56,1.55,1.80,1.53,1.53,1.66,2.09 | 300 | 200 | 1 |
| 9 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.68,1.68,1.68,1.61,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.74,1.69,1.67,1.67,1.64,1.69 | 300 | 200 | 1 |
| 11 | 20 | 1.33 | 1.33 | 2.05 | 1.62,1.63,1.62,1.63,1.62,1.62,1.68,1.68,1.63,1.25,1.71,1.71,1.90,2.08,1.65,1.65,1.63,1.58,1.68,1.68,1.64,1.26,1.72,1.72,1.54,2.06 | 300 | 200 | 1 |
| 12 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 20 | 4.88 | 4.00 | 7.50 | 1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.12,1.13,1.15,1.12,1.12,1.28,1.13,1.13,1.13,1.13,1.13,1.12,1.12,1.13,3.95,1.12,1.12,1.09,1.12 | 300 | 200 | 1 |
| 14 | 20 | 4.88 | 4.00 | 7.50 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.13,1.13,1.13,1.14,1.14,1.13,1.13,1.13,1.13,1.13,1.13,1.11,1.13,1.13,1.13,1.14,1.17 | 300 | 200 | 1 |
| 15 | 20 | 7.88 | 7.88 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 20 | 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 | 7 | 32.56 | 32.56 | 15.51 | - | 300 | 200 | 1 |
| 102 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.25,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.39,1.18,1.18,1.12,1.17 | 300 | 200 | 1 |
| 104 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.62,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69 | 300 | 200 | 1 |
| 105 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.78,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,2.08,1.67,1.67,1.61,1.66 | 300 | 200 | 1 |
| 106 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.26,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.74,1.18,1.18,1.12,1.17 | 300 | 200 | 1 |
| 107 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.69,1.67,1.67,1.79,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.11,1.67,1.67,1.61,1.66 | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 108 | 20 | 1.33 | 1.33 | 2.05 | 2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.07,2.10,2.10,2.08,2.00,2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.07,2.10,2.10,2.08,1.88 | 300 | 200 | 1 |
| 109 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.62,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69 | 300 | 200 | 1 |
| 111 | 20 | 1.33 | 1.33 | 2.05 | 2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.07,2.09,1.92,2.07,2.07,2.35,1.72,2.08,2.08,2.09,2.10,2.07,2.07,2.09,1.05,2.06,2.06,2.06,1.81 | 300 | 200 | 1 |
| 112 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 20 | 4.88 | 4.00 | 7.50 | 1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.02,1.05,1.05,1.26,1.21,1.05,1.05,1.05,1.04,1.05,1.05,1.05,1.01,1.05,1.05,1.04,1.14 | 300 | 200 | 1 |
| 114 | 20 | 4.88 | 4.00 | 7.50 | 1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.06,1.14,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.04,1.05,1.24 | 300 | 200 | 1 |
| 115 | 20 | 6.63 | 6.63 | 10.20 | 1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.15,1.30,1.14,1.14,1.18,1.10,1.15,1.15,1.15,1.16,1.14,1.14,1.15,1.90,1.14,1.14,1.14,1.11 | 300 | 200 | 1 |
| 116 | 20 | 6.63 | 6.63 | 10.20 | 1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.16,1.16,1.14,1.16,1.16,1.14,1.12,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.13,1.16,1.16,1.15,1.11 | 300 | 200 | 1 |
| 201 | 7 | 32.56 | 32.56 | 15.51 | - | 300 | 200 | 1 |
| 202 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.25,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.91,1.18,1.18,1.12,1.17 | 300 | 200 | 1 |
| 204 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.68,1.67,1.68,1.68,1.62,1.69,1.67,1.67,1.67,1.67,1.68,1.68,1.73,1.69,1.67,1.67,1.64,1.69 | 300 | 200 | 1 |
| 205 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.69,1.67,1.67,1.78,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.11,1.67,1.67,1.60,1.66 | 300 | 200 | 1 |
| 206 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.25,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.90,1.18,1.18,1.12,1.17 | 300 | 200 | 1 |
| 207 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.69,1.67,1.67,1.78,1.65,1.67,1.67,1.67,1.67,1.67,1.67,1.69,1.11,1.67,1.67,1.60,1.66 | 300 | 200 | 1 |
| 208 | 20 | 1.33 | 1.33 | 2.05 | 2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.09,2.07,2.07,2.09,2.09,2.10,2.06,2.08,2.08,2.08,2.08,2.09,2.09,2.06,2.07,2.09,2.09,2.09,1.97 | 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 | 251.16 | 41.64 | 42.30 | 42.30 | 75.35 | 75.35 |
| 2 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 3 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 4 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 5 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 6 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 7 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 8 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 9 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 10 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 11 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 12 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 13 | 159.30 | 116.35 | 33.31 | 6.46 | 56.26 | 44.91 |
| 14 | 159.30 | 116.35 | 33.92 | 6.46 | 56.26 | 44.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 16 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 101 | 251.16 | 41.64 | 42.30 | 42.30 | 75.35 | 75.35 |
| 102 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 103 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 104 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 105 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 106 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 107 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 108 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 109 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 110 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 111 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 112 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 113 | 159.30 | 116.35 | 30.87 | 6.46 | 56.26 | 44.91 |
| 114 | 159.30 | 116.35 | 31.78 | 6.46 | 56.26 | 44.91 |
| 115 | 159.30 | 75.13 | 21.18 | 6.46 | 56.26 | 44.91 |
| 116 | 159.30 | 75.13 | 21.38 | 6.46 | 56.26 | 44.91 |
| 201 | 251.16 | 41.64 | 42.30 | 42.30 | 75.35 | 75.35 |
| 202 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 203 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 204 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 205 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 206 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 207 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 208 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.380 | 0.377 | 0.030 | 0.008 | 0.002 | 0.574 | #21 | 0.870 | Not Required | Pass |
| 2 | 0.001 | 0.469 | 0.033 | 0.099 | 0.004 | 0.503 | #21 | 0.036 | Not Required | Pass |
| 3 | 0.004 | 0.697 | 0.016 | 0.069 | 0.002 | 0.715 | #21 | 0.046 | Not Required | Pass |
| 4 | 0.003 | 0.665 | 0.057 | 0.066 | 0.013 | 0.707 | #21 | 0.082 | Not Required | Pass |
| 5 | 0.004 | 0.432 | 0.055 | 0.069 | 0.014 | 0.444 | #21 | 0.076 | Not Required | Pass |
| 6 | 0.004 | 0.747 | 0.035 | 0.075 | 0.007 | 0.783 | #21 | 0.046 | Not Required | Pass |
| 7 | 0.005 | 0.463 | 0.083 | 0.074 | 0.021 | 0.484 | #21 | 0.076 | Not Required | Pass |
| 8 | 0.001 | 0.088 | 0.086 | 0.044 | 0.009 | 0.131 | #21 | 0.102 | Not Required | Pass |
| 9 | 0.006 | 0.078 | 0.027 | 0.001 | 0.001 | 0.108 | #21 | 0.206 | Not Required | Pass |
| 10 | 0.005 | 0.702 | 0.077 | 0.070 | 0.017 | 0.747 | #21 | 0.082 | Not Required | Pass |
| 11 | 0.001 | 0.089 | 0.088 | 0.047 | 0.009 | 0.131 | #21 | 0.102 | Not Required | Pass |
| 12 | 0.001 | 0.516 | 0.035 | 0.106 | 0.005 | 0.550 | #21 | 0.054 | Not Required | Pass |
| 13 | 0.003 | 0.222 | 0.219 | 0.061 | 0.012 | 0.355 | #21 | 0.306 | Not Required | Pass |
| 14 | 0.003 | 0.212 | 0.217 | 0.058 | 0.012 | 0.356 | #24 | 0.204 | Not Required | Pass |
| 15 | 0.000 | 0.067 | 0.074 | 0.030 | 0.006 | 0.141 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.064 | 0.074 | 0.028 | 0.006 | 0.138 | #21 | Not Required | Not Required | Pass |
| 101 | 0.441 | 0.392 | 0.003 | 0.009 | 0.000 | 0.647 | #21 | 0.870 | Not Required | Pass |
| 102 | 0.002 | 0.575 | 0.039 | 0.120 | 0.004 | 0.615 | #21 | 0.036 | Not Required | Pass |
| 103 | 0.005 | 0.837 | 0.029 | 0.083 | 0.004 | 0.869 | #21 | 0.046 | Not Required | Pass |
| 104 | 0.005 | 0.805 | 0.084 | 0.080 | 0.018 | 0.862 | #21 | 0.082 | Not Required | Pass |
| 105 | 0.005 | 0.519 | 0.087 | 0.083 | 0.022 | 0.541 | #21 | 0.076 | Not Required | Pass |
| 106 | 0.005 | 0.839 | 0.028 | 0.084 | 0.004 | 0.865 | #21 | 0.046 | Not Required | Pass |
| 107 | 0.005 | 0.521 | 0.080 | 0.083 | 0.020 | 0.542 | #21 | 0.076 | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 108 | 0.001 | 0.055 | 0.086 | 0.047 | 0.009 | 0.121 | #24 | 0.102 | Not Required | Pass |
| 109 | 0.008 | 0.083 | 0.022 | 0.001 | 0.000 | 0.108 | #21 | 0.206 | Not Required | Pass |
| 110 | 0.005 | 0.799 | 0.078 | 0.080 | 0.017 | 0.851 | #21 | 0.082 | Not Required | Pass |
| 111 | 0.002 | 0.061 | 0.087 | 0.049 | 0.009 | 0.120 | #24 | 0.102 | Not Required | Pass |
| 112 | 0.002 | 0.573 | 0.039 | 0.119 | 0.005 | 0.613 | #21 | 0.036 | Not Required | Pass |
| 113 | 0.003 | 0.252 | 0.237 | 0.064 | 0.012 | 0.455 | #21 | 0.306 | Not Required | Pass |
| 114 | 0.004 | 0.258 | 0.235 | 0.062 | 0.012 | 0.458 | #21 | 0.306 | Not Required | Pass |
| 115 | 0.003 | 0.341 | 0.116 | 0.050 | 0.010 | 0.458 | #21 | 0.507 | Not Required | Pass |
| 116 | 0.001 | 0.324 | 0.118 | 0.049 | 0.010 | 0.439 | #21 | 0.507 | Not Required | Pass |
| 201 | 0.435 | 0.399 | 0.000 | 0.009 | 0.000 | 0.640 | #21 | 0.870 | Not Required | Pass |
| 202 | 0.001 | 0.566 | 0.038 | 0.118 | 0.005 | 0.606 | #21 | 0.036 | Not Required | Pass |
| 203 | 0.005 | 0.829 | 0.028 | 0.083 | 0.004 | 0.859 | #21 | 0.046 | Not Required | Pass |
| 204 | 0.005 | 0.788 | 0.076 | 0.079 | 0.016 | 0.841 | #21 | 0.082 | Not Required | Pass |
| 205 | 0.005 | 0.514 | 0.079 | 0.082 | 0.020 | 0.535 | #21 | 0.076 | Not Required | Pass |
| 206 | 0.005 | 0.829 | 0.028 | 0.083 | 0.004 | 0.859 | #21 | 0.046 | Not Required | Pass |
| 207 | 0.005 | 0.514 | 0.079 | 0.082 | 0.020 | 0.535 | #21 | 0.076 | Not Required | Pass |
| 208 | 0.001 | 0.056 | 0.083 | 0.046 | 0.009 | 0.121 | #21 | 0.102 | 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 |
|---|---|---|

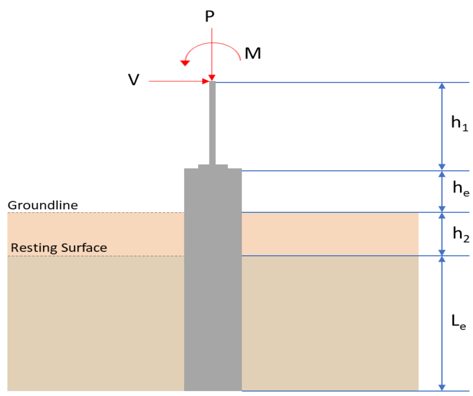
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 6.75 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 9.399 | 15.830 |
| $V_x$ (kip) | -0.383 | -0.641 |
| $V_z$ (kip) | 0.069 | 0.123 |
| $M_x$ (kipft) | 0.355 | 0.636 |
| $M_z$ (kipft) | 8.408 | 15.961 |

**Material Properties**

$f'_{ck} = 3 \text{ ksi}$ - 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,

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

$$H_o = \frac{(-0.383 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.12767 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(8.408 \text{ kipft}) + ((-0.383 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.8027 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.4953 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.069 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.023 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.355 \text{ kipft}) + ((0.069 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.11833 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.7517 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.4953 \text{ ft}), (2.7517 \text{ ft})]$$

$$L_{e,req} = 6.495 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.495 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.96222$$

Status: **PASS**
Ratio: **0.960**

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(9.4 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

| | | | |
|---|---|---|---|
| | $$q = 1.3297\ \mathrm{kip/ft^2}$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(1.3297\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$ $$Ratio = 0.66484$$ | Status: **PASS** Ratio: **0.660** |
| *Czerniak* | **Lateral Soil Pressure (ASD):** $L/D$ - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(6.75\ \mathrm{ft})}{(36\ \mathrm{in})}$$ $$L/D = 2.25$$ Since L/D $\leq$ 10, Pile is short. **Considering x-direction:** $H_o = -0.12767\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 2.8027\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, $a$ - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (2.8027\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.12767\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (2.8027\ \mathrm{kipft/ft})) + (4 \times (-0.12767\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$ $$a = 4.5957\ \mathrm{ft}$$ $p$ - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (2.8027\ \mathrm{kipft/ft})) + (3 \times (-0.12767\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (2.8027\ \mathrm{kipft/ft})) + (2 \times (-0.12767\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$ $$p = 0.28776\ \mathrm{kip/ft^2}$$ $s$ - Earth pressure against the pile at distance $L_e$, $$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (2.8027\ \mathrm{kipft/ft})) + ((-0.12767\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$ $$s = 0.98125\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** $p_a$ - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.5957\ \mathrm{ft})}{2}$$ $$p_a = 0.34468\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.28776\ \mathrm{kip/ft^2})}{(0.34468\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.83487$$ | Status: **PASS** Ratio: **0.830** |

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.98125\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96914$$

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

**Considering z-direction:**

$H_o = 0.023\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11833\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11833\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.11833\ \mathrm{kipft/ft})) + (4 \times (0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7624\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.11833\ \mathrm{kipft/ft})) + (3 \times (0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\,2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.11833\ \mathrm{kipft/ft})) + (2 \times (0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.034261\ \mathrm{kip/ft^2}$$

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

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.11833\ \mathrm{kipft/ft})) + ((0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.081071\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7624\ \mathrm{ft})}{2}$$

$$p_a = 0.35718\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.034261\ \mathrm{kip/ft^2}\right)}{\left(0.35718\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.09592$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

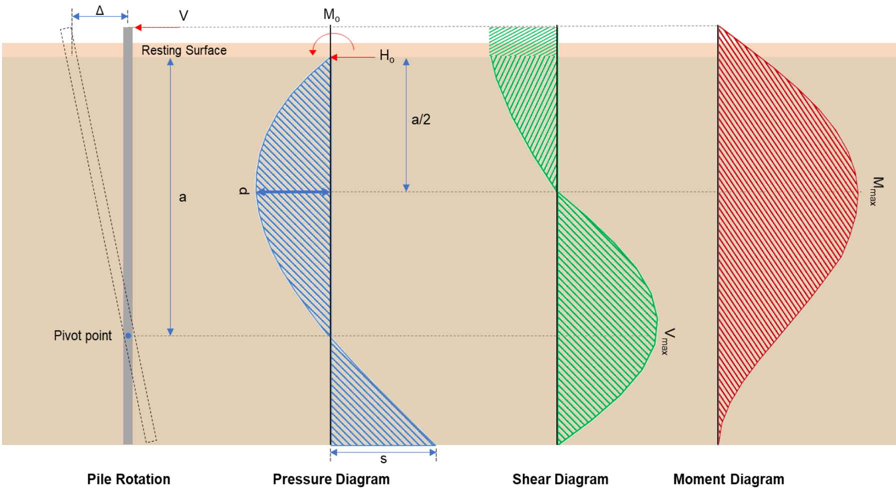
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.081071\ \text{kip/ft}^2)}{(1.0125\ \text{kip/ft}^2)}$$

$$Ratio = 0.08007$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.641\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.21367\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(15.961\ \text{kipft}) + ((-0.641\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 5.3203\ \text{kipft/ft}$$

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

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

$$E = \frac{(5.3203\ \text{kipft/ft})}{(-0.21367\ \text{kip/ft})}$$

$$E = 24.9\ \text{ft}$$

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

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

$$a = \frac{(4 \times (5.3203\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.21367\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (5.3203\ \text{kipft/ft})) + (4 \times (-0.21367\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.5861\ \text{ft}$$

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

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

$$V_{max} = ((-0.21367\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (24.9\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.5861\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (24.9\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.5861\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.6128 \text{ kip}$$

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

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

$$M_{max} = ((-0.21367 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(24.9 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 15.172 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.123 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.041 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.636 \text{ kipft}) + ((0.123 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.212 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.212 \text{ kipft/ft})}{(0.041 \text{ kip/ft})}$$

$$E = 5.1707 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.212 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (0.041 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.212 \text{ kipft/ft})) + (4 \times (0.041 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.7617 \text{ ft}$$

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

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

$$V_{max} = ((0.041 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.7617 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.7617 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.24819 \text{ kip}$$

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

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

$$M_{max} = ((0.041 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(5.1707 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.76314 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.83 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.681 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-44.681 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

*25.7.2.2* Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
*25.7.2.1* $s_{ties}$ - Maximum center-to-center spacing of ties,

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

$$s_{ties} = Min\left[\left(16 \times (0.625 \text{ in})\right), \left(48 \times (0.375 \text{ in})\right), (36 \text{ in})\right]$$

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

**Summary:**

| | | |
|---|---|---|
| | Main reinforcement: **6 - #5 (0.625 in)**<br>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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.83\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$

$$Ratio = 0.010606$$

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

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

**Parameters:**

$b_w = 36\ \mathrm{in}$ - Effective width,

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \mathrm{in})$$

$$d = 28.8\ \mathrm{in}$$

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 203.86\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 15.83\ \mathrm{kip} \rightarrow 15830\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(15830\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 84.23\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 237.06\ \mathrm{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (84.23\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 84.23 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

$A_v$ - 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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.23 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.56 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 4.6128 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.6128 \text{ kip})}{(79.56 \text{ kip})}$$

$$Ratio = 0.057979$$

Status: **PASS**
Ratio: **0.060**

**Considering z-direction:**

$V_{max} = 0.24819 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.24819 \text{ kip})}{(79.56 \text{ kip})}$$

$$Ratio = 0.0031195$$

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

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

$S_m$ - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

$$S_m = 4580.4 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 67.947kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
$\phi M_n$ - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 15.172$ kipft - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.172 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.22329$$

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

**Considering z-direction:**

$M_{max} = 0.76314$ kipft - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.76314 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.011231$$

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

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

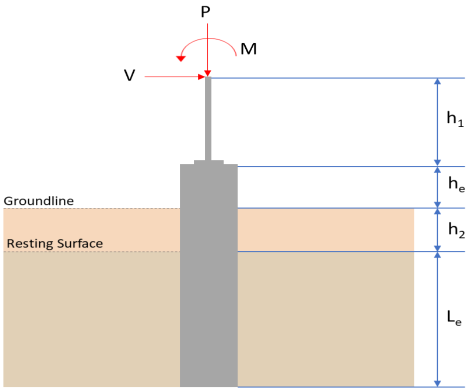
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 6.75\ \mathrm{ft}$ - 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) | 9.399 | 15.830 |
| $V_x$ (kip) | -0.383 | -0.641 |
| $V_z$ (kip) | -0.069 | -0.123 |
| $M_x$ (kipft) | -0.355 | -0.636 |
| $M_z$ (kipft) | 8.408 | 15.961 |

**Material Properties**

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.383\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.12767\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(8.408\ \text{kipft}) + ((-0.383\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 2.8027\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.4953\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.069\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.023\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.355\ \text{kipft}) + ((-0.069\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.11833\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.1667\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.4953\ \text{ft}), (2.1667\ \text{ft})]$$

$$L_{e,req} = 6.495\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.495\ \text{ft})}{(6.75\ \text{ft})}$$

$$Ratio = 0.96222$$

Status: **PASS**
Ratio: **0.960**

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(9.4\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.3297\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.3297\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.66484$$

Status: **PASS**
Ratio: **0.660**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.25$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.12767\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.8027\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.8027\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.12767\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (2.8027\ \text{kipft/ft})) + (4 \times (-0.12767\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.5957\ \text{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.8027\ \text{kipft/ft})) + (3 \times (-0.12767\ \text{kip/ft}) \times (6.75\ \text{ft}))]^{\ 2}}{(6.75\ \text{ft})^2 \times [(3 \times (2.8027\ \text{kipft/ft})) + (2 \times (-0.12767\ \text{kip/ft}) \times (6.75\ \text{ft}))]}$$

$$p = 0.28776\ \text{kip/ft}^2$$

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

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.8027\ \text{kipft/ft})) + ((-0.12767\ \text{kip/ft}) \times (6.75\ \text{ft})]}{(6.75\ \text{ft})^2}$$

$$s = 0.98125\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.5957\ \text{ft})}{2}$$

$$p_a = 0.34468\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.28776\ \text{kip/ft}^2)}{(0.34468\ \text{kip/ft}^2)}$$

$$Ratio = 0.83487$$

Status: **PASS**
Ratio: **0.830**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.98125\ \mathrm{kip/ft^2}\right)}{\left(1.0125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96914$$

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

**Considering z-direction:**

$H_o = -0.023\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11833\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11833\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.11833\ \mathrm{kipft/ft})) + (4 \times (-0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.7624\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.11833\ \mathrm{kipft/ft})) + (3 \times (-0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.11833\ \mathrm{kipft/ft})) + (2 \times (-0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.000033412\ \mathrm{kip/ft^2}$$

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

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.11833\ \mathrm{kipft/ft})) + ((-0.023\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.016842\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7624\ \mathrm{ft})}{2}$$

$$p_a = 0.35718\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000033412\ \mathrm{kip/ft^2}\right)}{\left(0.35718\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000093542$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.0125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

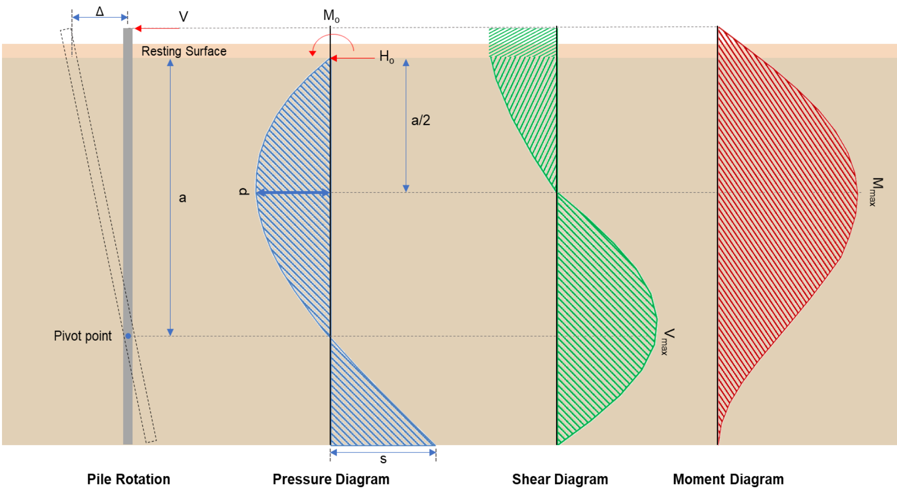
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.016842 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.016634$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.641 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.21367 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(15.961 \text{ kipft}) + ((-0.641 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.3203 \text{ kipft/ft}$$

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

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

$$E = \frac{(5.3203 \text{ kipft/ft})}{(-0.21367 \text{ kip/ft})}$$

$$E = 24.9 \text{ ft}$$

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

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

$$a = \frac{(4 \times (5.3203 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.21367 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (5.3203 \text{ kipft/ft})) + (4 \times (-0.21367 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.5861 \text{ ft}$$

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

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

$$V_{max} = ((-0.21367 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.5861 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.5861 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 4.6128 \text{ kip}$$

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

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

$$M_{max} = ((-0.21367 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(24.9 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (24.9 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.5861 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 15.172 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.123 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.041 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.636 \text{ kipft}) + ((-0.123 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.212 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.212 \text{ kipft/ft})}{(-0.041 \text{ kip/ft})}$$

$$E = 5.1707 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.212 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.041 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.212 \text{ kipft/ft})) + (4 \times (-0.041 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.7617 \text{ ft}$$

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

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

$$V_{max} = ((-0.041 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.7617 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.7617 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.24819 \text{ kip}$$

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

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

$$M_{max} = ((-0.041 \text{ kip/ft}) \times (36 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(5.1707 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (5.1707 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.7617 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.76314 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.83 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.681 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-44.681 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{\left(1.8322 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322 \text{ in}^2\right)}{\left(1.8408 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

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

*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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.83\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.010606$$

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

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

**Parameters:**

$b_w = 36\ \text{in}$ - Effective width,

*22.5.2.2* $d$ - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

*22.5.5.1.3* $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 203.86\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 15.83\ \text{kip} \rightarrow 15830\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(15830\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 84.23\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 237.06\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \text{kip}), (84.23\ \text{kip}), (237.06\ \text{kip})\right]$$

$$V_c = 84.23 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

$A_v$ - 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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.23 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.56 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 4.6128 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.6128 \text{ kip})}{(79.56 \text{ kip})}$$

$$Ratio = 0.057979$$

Status: **PASS**
Ratio: **0.060**

**Considering z-direction:**

$V_{max} = 0.24819 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.24819 \text{ kip})}{(79.56 \text{ kip})}$$

$$Ratio = 0.0031195$$

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

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

$S_m$ - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

$$S_m = 4580.4\ \text{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 67.947kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 632.67\ \text{kipft}$$

Therefore,
$\phi M_n$ - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947\ \text{kipft}), (632.67\ \text{kipft})]$$

$$\phi M_n = 67.947\ \text{kipft}$$

**Considering x-direction:**

$M_{max} = 15.172\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.172\ \text{kipft})}{(67.947\ \text{kipft})}$$

$$Ratio = 0.22329$$

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

**Considering z-direction:**

$M_{max} = 0.76314\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.76314\ \text{kipft})}{(67.947\ \text{kipft})}$$

$$Ratio = 0.011231$$

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

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

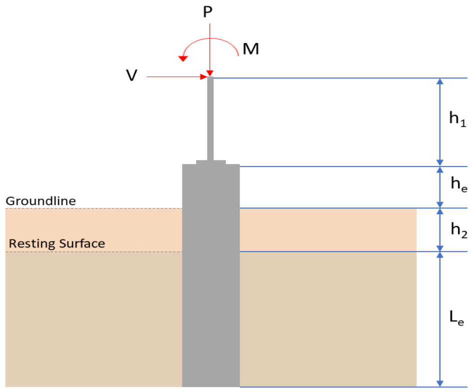
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 7\ \mathrm{ft}$ - 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) | 10.889 | 18.375 |
| $V_x$ (kip) | -0.411 | -0.683 |
| $V_z$ (kip) | -0.006 | -0.013 |
| $M_x$ (kipft) | -0.033 | -0.065 |
| $M_z$ (kipft) | 8.775 | 16.569 |

**Material Properties**

$f'_{ck} = 3\ \mathrm{ksi}$ - 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,

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

$$H_o = \frac{(-0.411\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.137\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(8.775 \text{ kipft}) + ((-0.411 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.925 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.5639 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.006 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.002 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.033 \text{ kipft}) + ((-0.006 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.011 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.0576 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.5639 \text{ ft}), (1.0576 \text{ ft})]$$

$$L_{e,req} = 6.564 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.564 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.93771$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(10.889 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.5405 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.5405 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.77024$$

Status: **PASS**
Ratio: **0.770**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.3333$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.137 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.925 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.925 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.137 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (2.925 \text{ kipft/ft})) + (4 \times (-0.137 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7713 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.925 \text{ kipft/ft})) + (3 \times (-0.137 \text{ kip/ft}) \times (7 \text{ ft}))]^{\,2}}{(7 \text{ ft})^2 \times [(3 \times (2.925 \text{ kipft/ft})) + (2 \times (-0.137 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.27293 \text{ kip/ft}^2$$

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

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.925 \text{ kipft/ft})) + ((-0.137 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.94077 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.7713 \text{ ft})}{2}$$

$$p_a = 0.35785 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27293 \text{ kip/ft}^2)}{(0.35785 \text{ kip/ft}^2)}$$

$$Ratio = 0.76269$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.94077\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89597$$

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

**Considering z-direction:**

$H_o = -0.002\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times (0.011\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})\right) + \left(3 \times (-0.002\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{\left(6 \times (0.011\ \mathrm{kipft/ft})\right) + \left(4 \times (-0.002\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})\right)}$$

$$a = 4.9344\ \mathrm{ft}$$

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

$$p = \frac{1.178\left[\left(4\,M_o\right) + \left(3\,H_o\,L_e\right)\right]^2}{L_e^2\left[\left(3\,M_o\right) + \left(2\,H_o\,L_e\right)\right]}$$

$$p = \frac{1.178 \times \left[\left(4 \times (0.011\ \mathrm{kipft/ft})\right) + \left(3 \times (-0.002\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})\right)\right]^2}{(7\ \mathrm{ft})^2 \times \left[\left(3 \times (0.011\ \mathrm{kipft/ft})\right) + \left(2 \times (-0.002\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})\right)\right]}$$

$$p = 0.000019233\ \mathrm{kip/ft^2}$$

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

$$s = \frac{9.425\left[\left(2\,M_o\right) + \left(H_o\,L_e\right)\right]}{L_e^2}$$

$$s = \frac{9.425 \times \left[\left(2 \times (0.011\ \mathrm{kipft/ft})\right) + \left((-0.002\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})\right)\right]}{(7\ \mathrm{ft})^2}$$

$$s = 0.0015388\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9344\ \mathrm{ft})}{2}$$

$$p_a = 0.37008\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000019233\ \mathrm{kip/ft^2}\right)}{\left(0.37008\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000051969$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

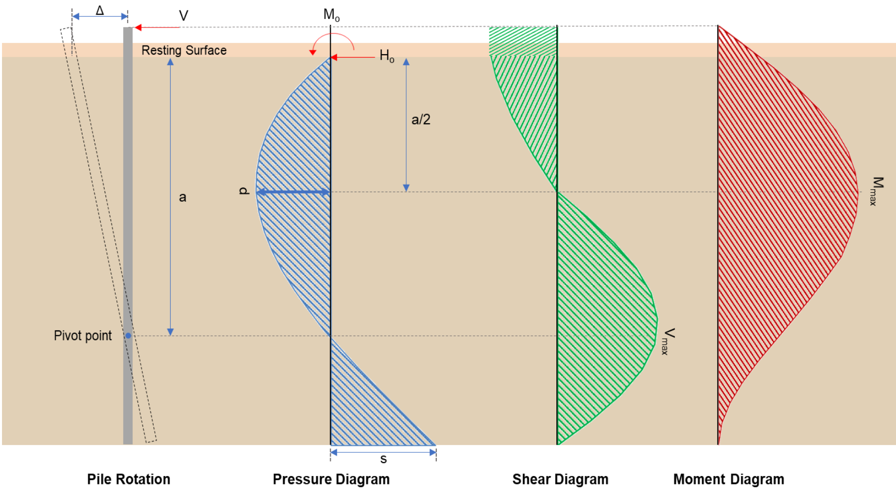
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(0.0015388\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0014655$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.683\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.22767\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(16.569\ \mathrm{kipft}) + ((-0.683\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 5.523\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(5.523\ \mathrm{kipft/ft})}{(-0.22767\ \mathrm{kip/ft})}$$

$$E = 24.259\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (5.523\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.22767\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (5.523\ \mathrm{kipft/ft})) + (4 \times (-0.22767\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.7608\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.22767\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (24.259\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.7608\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (24.259\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.7608\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.6442 \text{ kip}$$

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

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

$$M_{max} = ((-0.22767 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(24.259 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (24.259 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (24.259 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 15.817 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.013 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0043333 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.065 \text{ kipft}) + ((-0.013 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.021667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.021667 \text{ kipft/ft})}{(-0.0043333 \text{ kip/ft})}$$

$$E = 5 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.021667 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.0043333 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.021667 \text{ kipft/ft})) + (4 \times (-0.0043333 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9483 \text{ ft}$$

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

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

$$V_{max} = ((-0.0043333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (5 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9483 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (5 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9483 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.025049 \text{ kip}$$

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

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

$$M_{max} = ((-0.0043333 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(5 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (5 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (5 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.079513 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(18.375 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.601 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-44.601 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

*25.7.2.2* Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
*25.7.2.1* $s_{ties}$ - Maximum center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.375\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.012312$$

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

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

**Parameters:**

$b_w = 36\ \text{in}$ - Effective width,
22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 203.86\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 18.375\ \text{kip} \rightarrow 18375\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(18375\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 84.662\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 237.06\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \text{kip}), (84.662\ \text{kip}), (237.06\ \text{kip})\right]$$

$$V_c = 84.662\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{s,a} = 454.3\ \mathrm{kip}$$

$A_v$ - 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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (28.8\ \mathrm{in})}{(10\ \mathrm{in})}$$

$$V_{s,b} = 38.17\ \mathrm{kip}$$

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3\ \mathrm{kip}), (38.17\ \mathrm{kip})\right]$$

$$V_s = 38.17\ \mathrm{kip}$$

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.662\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 79.841\ \mathrm{kip}$$

**Considering x-direction:**

$V_{max} = 4.6442\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.6442\ \mathrm{kip})}{(79.841\ \mathrm{kip})}$$

$$Ratio = 0.058168$$

Status: **PASS**
Ratio: **0.060**

**Considering z-direction:**

$V_{max} = 0.025049\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.025049\ \mathrm{kip})}{(79.841\ \mathrm{kip})}$$

$$Ratio = 0.00031373$$

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

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

$S_m$ - Section modulus

$$S_m = \frac{\pi\ D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$

$$S_m = 4580.4\ \mathrm{in}^3$$

|  |  |  |
|---|---|---|
|  | $$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 67.947 kipft$$ |  |
| *14.5.2.1b* | $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 632.67\ \text{kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(67.947\ \text{kipft}), (632.67\ \text{kipft})]$$ $$\phi M_n = 67.947\ \text{kipft}$$ **Considering x-direction:**<br>$M_{max} = 15.817\ \text{kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(15.817\ \text{kipft})}{(67.947\ \text{kipft})}$$ $$Ratio = 0.23279$$ | Status: **PASS**<br>Ratio: **0.230** |
|  | **Considering z-direction:**<br>$M_{max} = 0.079513\ \text{kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.079513\ \text{kipft})}{(67.947\ \text{kipft})}$$ $$Ratio = 0.0011702$$ | Status: **PASS**<br>Ratio: **0.000** |

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

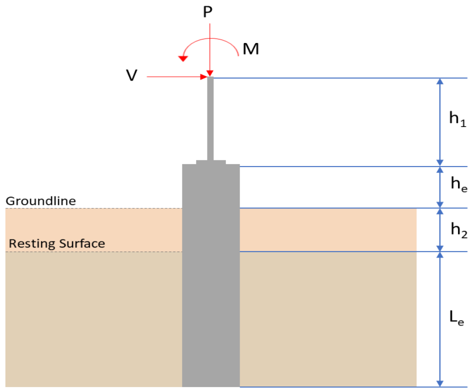
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 7\ \text{ft}$ - 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) | 10.737 | 18.127 |
| $V_x$ (kip) | -0.410 | -0.684 |
| $V_z$ (kip) | 0.000 | 0.000 |
| $M_x$ (kipft) | 0.000 | 0.000 |
| $M_z$ (kipft) | 8.910 | 16.885 |

**Material Properties**

$f'_{ck} = 3\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-0.41\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.13667\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(8.91\ \text{kipft}) + ((-0.41\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 2.97\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.6049\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$L_{e,z} = 0\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.6049\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 6.605\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.605\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.94357$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(10.737\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.519\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.519\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.75949$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.3333$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.13667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.97\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.97\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.13667\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (2.97\ \mathrm{kipft/ft})) + (4 \times (-0.13667\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.7698\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\ M_o) + (3\ H_o\ L_e)]^2}{L_e^2\ [(3\ M_o) + (2\ H_o\ L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.97\ \mathrm{kipft/ft})) + (3 \times (-0.13667\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^2}{(7\ \mathrm{ft})^2 \times [(3 \times (2.97\ \mathrm{kipft/ft})) + (2 \times (-0.13667\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.27894\ \mathrm{kip/ft^2}$$

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

$$s = \frac{9.425\ [(2\ M_o) + (H_o\ L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.97\ \mathrm{kipft/ft})) + ((-0.13667\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.95853\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.7698\ \mathrm{ft})}{2}$$

$$p_a = 0.35773\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27894\ \mathrm{kip/ft^2}\right)}{\left(0.35773\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.77974$$

Status: **PASS**
Ratio: **0.780**

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

$$p_s = R\ L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

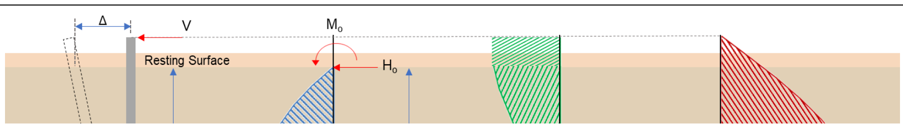
$Ratio$ - Lateral soil capacity

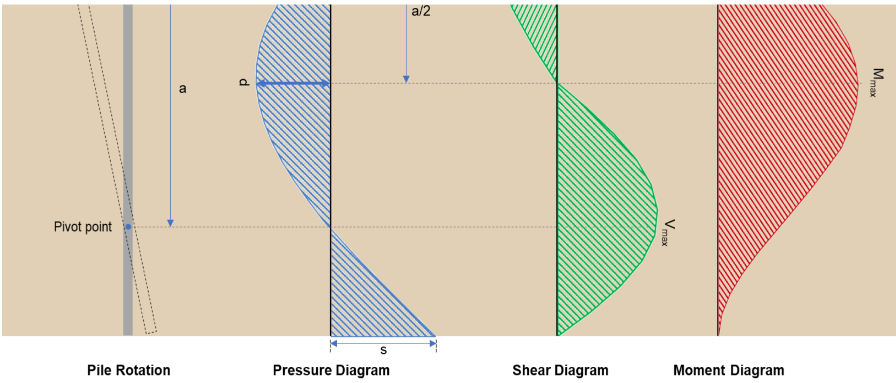
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.95853\ \mathrm{kip/ft^2}\right)}{\left(1.05\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91288$$

Status: **PASS**
Ratio: **0.910**






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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.684 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.228 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(16.885 \text{ kipft}) + ((-0.684 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.6283 \text{ kipft/ft}$$

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

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

$$E = \frac{(5.6283 \text{ kipft/ft})}{(-0.228 \text{ kip/ft})}$$

$$E = 24.686 \text{ ft}$$

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

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

$$a = \frac{(4 \times (5.6283 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.228 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (5.6283 \text{ kipft/ft})) + (4 \times (-0.228 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7594 \text{ ft}$$

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

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

$$V_{max} = ((-0.228 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (24.686 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.7594 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (24.686 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.7594 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 4.725 \text{ kip}$$

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

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

$$M_{max} = ((-0.228 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(24.686 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7594 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (24.686 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.7594 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (24.686 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.7594 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 16.099 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(18.127 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.609 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-44.609 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

*25.7.2.2* Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
*25.7.2.1* $s_{ties}$ - Maximum center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.127\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.012145$$

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

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

**Parameters:**

$b_w = 36$ in - Effective width,
*22.5.2.2* $d$ - Effective depth

$$d = 0.80\ D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

*22.5.5.1.3* $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \to 3000\ \text{psi}$,
*22.5.5.1.1* $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 203.86\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \to 3000\ \text{psi}$, $P = 18.127\ \text{kip} \to 18127\ \text{lbf}$,
*22.5.5.1.1(a)* $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(18127\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 84.62\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \to 3000\ \text{psi}$,
*22.5.5.1.2* $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 237.06\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \text{kip}), (84.62\ \text{kip}), (237.06\ \text{kip})\right]$$

$$V_c = 84.62 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

$A_v$ - 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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((84.62 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.814 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 4.725 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.725 \text{ kip})}{(79.814 \text{ kip})}$$

$$Ratio = 0.0592$$

Status: **PASS**
Ratio: **0.060**

---

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

$S_m$ - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 67.947kipft$$

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

| | | | |
|---|---|---|---|
| | $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(4580.4\text{ in}^3\right)$$ $$\phi M_{n,2} = 632.67\text{ kipft}$$ Therefore,<br>$\phi M_n$ - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(67.947\text{ kipft}), (632.67\text{ kipft})]$$ $$\phi M_n = 67.947\text{ kipft}$$ **Considering x-direction:**<br>$M_{max} = 16.099\text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(16.099\text{ kipft})}{(67.947\text{ kipft})}$$ $$Ratio = 0.23694$$ | Status: **PASS**<br>Ratio: **0.240** |

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

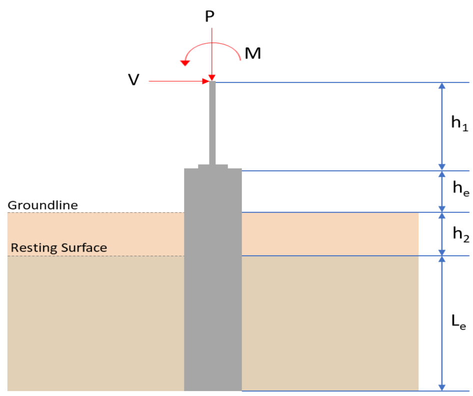
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 7 \text{ ft}$ - 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) | 10.889 | 18.375 |
| $V_x$ (kip) | -0.411 | -0.683 |
| $V_z$ (kip) | 0.006 | 0.013 |
| $M_x$ (kipft) | 0.033 | 0.065 |
| $M_z$ (kipft) | 8.775 | 16.569 |

**Material Properties**

$f'_{ck} = 3 \text{ ksi}$ - 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,

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

$$H_o = \frac{(-0.411 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.137 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(8.775 \text{ kipft}) + ((-0.411 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 2.925 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.5639 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.006 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.002 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.033 \text{ kipft}) + ((0.006 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.011 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.1703 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.5639 \text{ ft}), (1.1703 \text{ ft})]$$

$$L_{e,req} = 6.564 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.564 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.93771$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(10.889 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.5405\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.5405\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.77024$$

Status: **PASS**
Ratio: **0.770**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.3333$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.137\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.925\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.925\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.137\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (2.925\ \text{kipft/ft})) + (4 \times (-0.137\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.7713\ \text{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (2.925\ \text{kipft/ft})) + (3 \times (-0.137\ \text{kip/ft}) \times (7\ \text{ft}))]^2}{(7\ \text{ft})^2 \times [(3 \times (2.925\ \text{kipft/ft})) + (2 \times (-0.137\ \text{kip/ft}) \times (7\ \text{ft}))]}$$

$$p = 0.27293\ \text{kip/ft}^2$$

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

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (2.925\ \text{kipft/ft})) + ((-0.137\ \text{kip/ft}) \times (7\ \text{ft}))]}{(7\ \text{ft})^2}$$

$$s = 0.94077\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.7713\ \text{ft})}{2}$$

$$p_a = 0.35785\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.27293\ \text{kip/ft}^2)}{(0.35785\ \text{kip/ft}^2)}$$

$$Ratio = 0.76269$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.94077 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.89597$$

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

**Considering z-direction:**

$H_o = 0.002 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (0.002 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.011 \text{ kipft/ft})) + (4 \times (0.002 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9344 \text{ ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.011 \text{ kipft/ft})) + (3 \times (0.002 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.011 \text{ kipft/ft})) + (2 \times (0.002 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.0029149 \text{ kip/ft}^2$$

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

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.011 \text{ kipft/ft})) + ((0.002 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.0069245 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.9344 \text{ ft})}{2}$$

$$p_a = 0.37008 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0029149 \text{ kip/ft}^2)}{(0.37008 \text{ kip/ft}^2)}$$

$$Ratio = 0.0078762$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

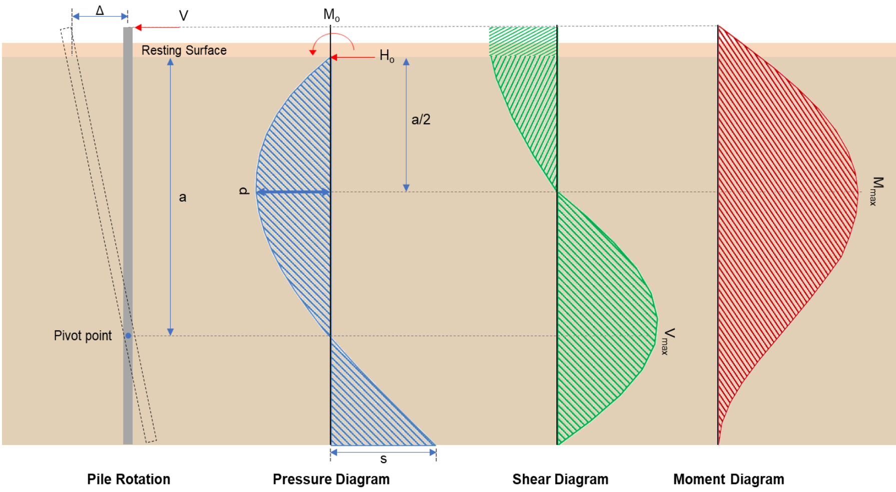
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0069245\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0065948$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.683\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.22767\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(16.569\ \mathrm{kipft}) + ((-0.683\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 5.523\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(5.523\ \mathrm{kipft/ft})}{(-0.22767\ \mathrm{kip/ft})}$$

$$E = 24.259\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (5.523\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.22767\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (5.523\ \mathrm{kipft/ft})) + (4 \times (-0.22767\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.7608\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.22767\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (24.259\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.7608\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (24.259\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.7608\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.6442 \text{ kip}$$

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

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

$$M_{max} = ((-0.22767 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(24.259 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (24.259 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (24.259 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7608 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 15.817 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.013 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0043333 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.065 \text{ kipft}) + ((0.013 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.021667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.021667 \text{ kipft/ft})}{(0.0043333 \text{ kip/ft})}$$

$$E = 5 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.021667 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (0.0043333 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.021667 \text{ kipft/ft})) + (4 \times (0.0043333 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9483 \text{ ft}$$

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

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

$$V_{max} = ((0.0043333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (5 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9483 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (5 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9483 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.025049 \text{ kip}$$

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

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

$$M_{max} = ((0.0043333 \text{ kip/ft}) \times (36 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(5 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (5 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (5 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9483 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.079513 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
*Table 22.4.2.1* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(18.375 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.601 \text{ in}^2$$

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

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

$$A_{min} = Max\left[(-44.601 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$Ratio = 0.99533$$

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

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

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

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

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

**Ties:**

*25.7.2.2* Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in)
*25.7.2.1* $s_{ties}$ - Maximum center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.375\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.012312$$

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

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

**Parameters:**

$b_w = 36\ \text{in}$ - Effective width,
*22.5.2.2* $d$ - Effective depth

$$d = 0.80\ D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

*22.5.5.1.3* $\lambda_s$ - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,
*22.5.5.1.1* $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 203.86\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 18.375\ \text{kip} \rightarrow 18375\ \text{lbf}$,
*22.5.5.1.1(a)* $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(18375\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 84.662\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,
*22.5.5.1.2* $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 237.06\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \text{kip}), (84.662\ \text{kip}), (237.06\ \text{kip})\right]$$

$$V_c = 84.662 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

$A_v$ - 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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((84.662 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 79.841 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 4.6442 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.6442 \text{ kip})}{(79.841 \text{ kip})}$$

$$Ratio = 0.058168$$

Status: **PASS**
Ratio: **0.060**

**Considering z-direction:**

$V_{max} = 0.025049 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.025049 \text{ kip})}{(79.841 \text{ kip})}$$

$$Ratio = 0.00031373$$

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

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

$S_m$ - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

$$S_m = 4580.4 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442 in^3$$

$$\phi M_{n,1} = 67.947 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
$\phi M_n$ - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 15.817 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.817 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.23279$$

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

**Considering z-direction:**

$M_{max} = 0.079513 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.079513 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.0011702$$

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