# Your Project Calculations

Project Name: Simmons_18mods

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Simmons_18mods&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=XjcjhDZUgPaYANpExXdQuAb4JfzrUm6FSba8yhrO8pp2aBdltgWqzO1gnRN1XLnX

## Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 2P-15-8TOP-HD-45-L-4Hx5W-KC2A |
| **Duty Classification:** | HD |
| **Module Width:** | 41.10 in |
| **Module Length:** | 74.00in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 5 |
| **Total Number of Modules:** | 20 |
| **Desired Tilt Angle:** | 40 |
| **Front Edge Clearance:** | 5 |
| **Total Array Height at Tilt:** | 13.86 ft |
| **Total Frame Length:** | 30.00 ft |
| **Frame Weight:** | 1568 lbs |
| **Array Dimensions N/S:** | 13.87 ft |
| **Array Dimensions E/W:** | 31.25 ft |
| **Rail Length:** | 166.40 in |
| **Rail Spacing:** | 3.08 ft |
| **Rail Check:** | Not Checked |

## Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 40 |
| **Pole Length above Grade:** | 9.46 ft |
| **Number of Poles:** | 2 |
| **Pole Spacing:** | 15 ft |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 6.25 ft<br>Pile 2: 6.25 ft |
| **Foundation Volume:** | 7.407 $y^3$ |
| **Foundation Result:** | PASSED |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 5 Noble Rd, Pinedale, WY 82941, USA |
| **Wind Speed:** | 110 mph |
| **Snow Load:** | 70 psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.017690 ksf |

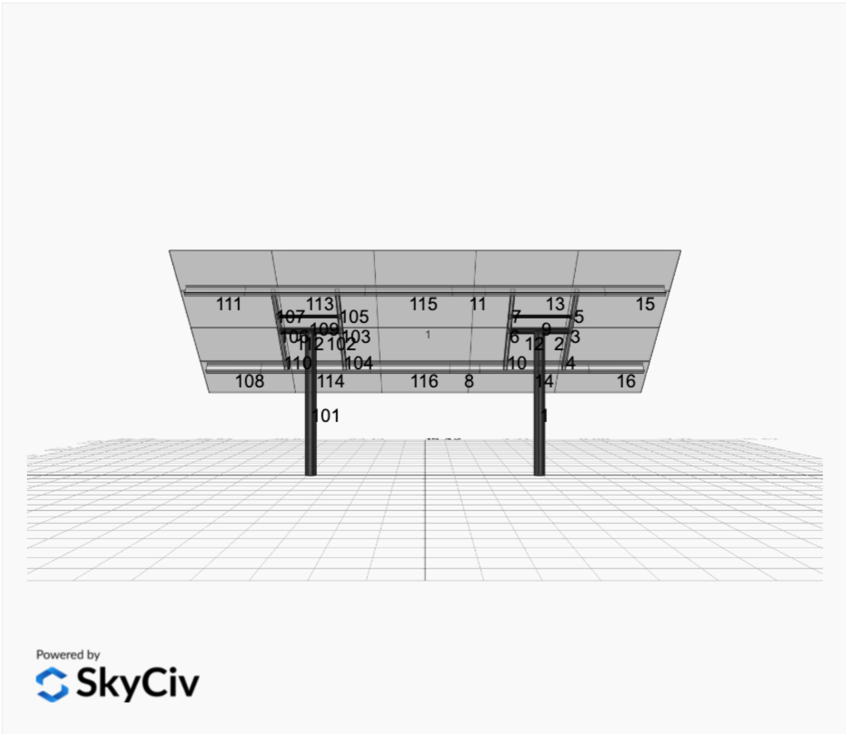

> **Design Disclaimer**
>
> This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

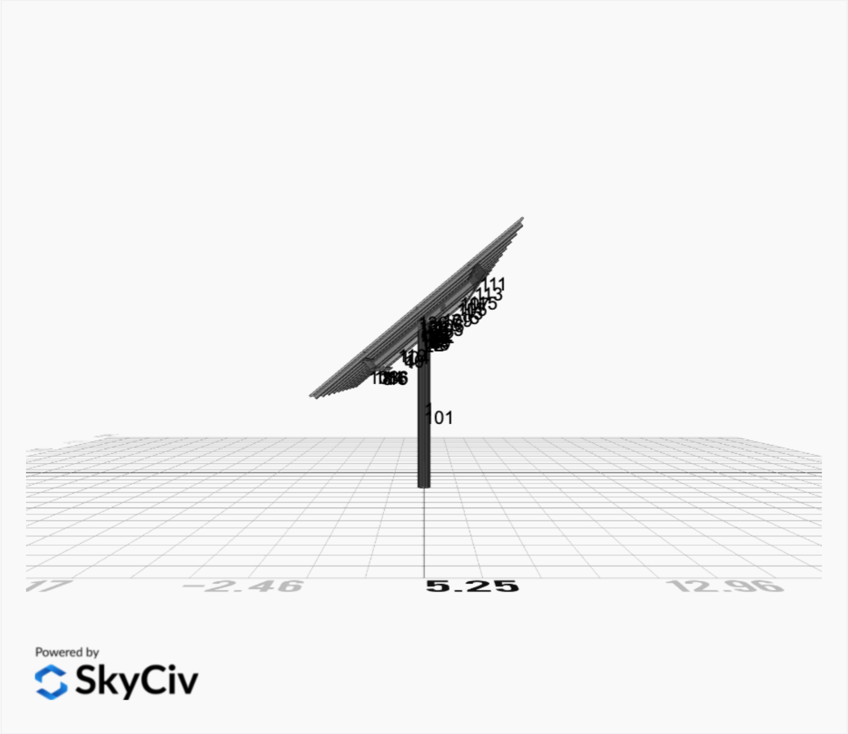
### AutoDesigner Input

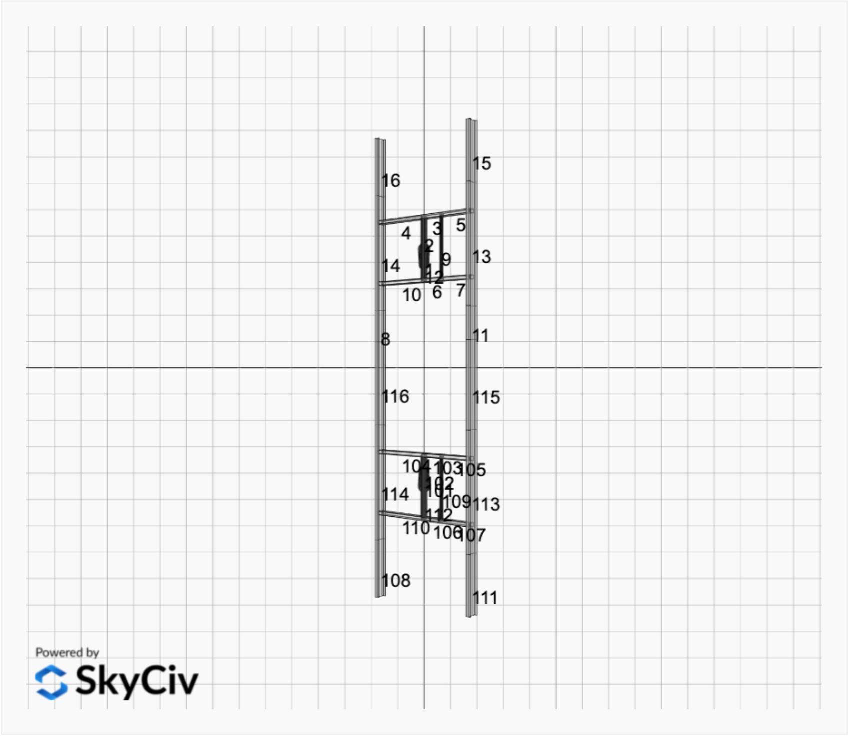
{"product_type":"Beam","project_id":"Simmons_18mods","site_address":"5 Noble Rd, Pinedale, WY 82941, USA","module_width":41.1,"module_length":74,"number_rows":"4","number_columns":5,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":40,"ground_clearance":5,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","foundation_type":"Square","foundation_size":48,"check_rails":false,"wind_speed_override":110,"snow_load_override":70,"direct_snow_load":false}

**Design Notes:**

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




101
-2.46
5.25
12.96
Powered by
SkyCiv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15
4
3
5
13
14
9
10
6
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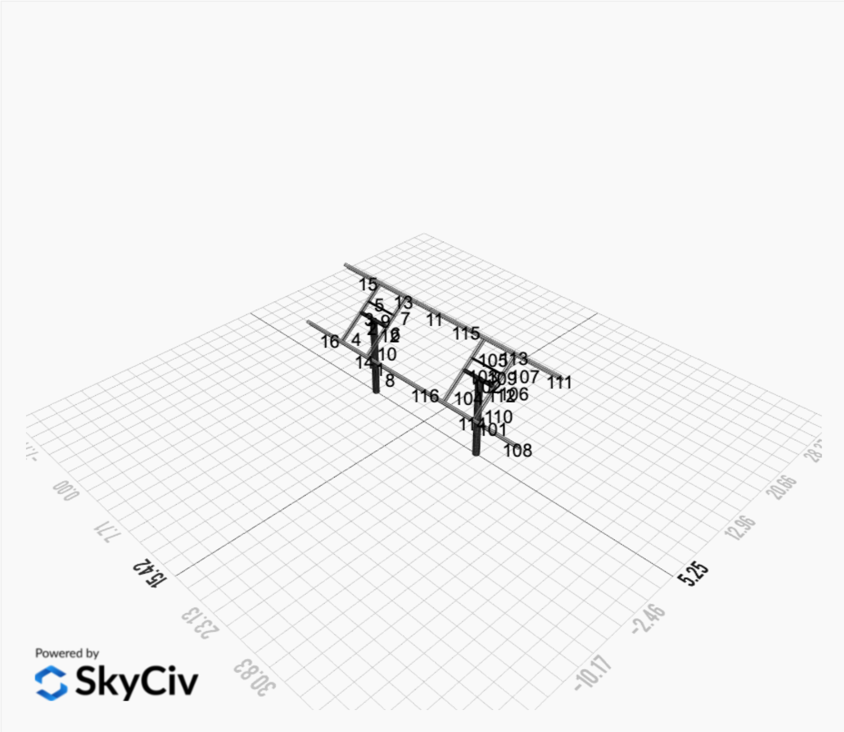
111
Powered by
SkyCiv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13
7
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4
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8
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5.25
12.96
20.66
-2.46
-10.17
Powered by
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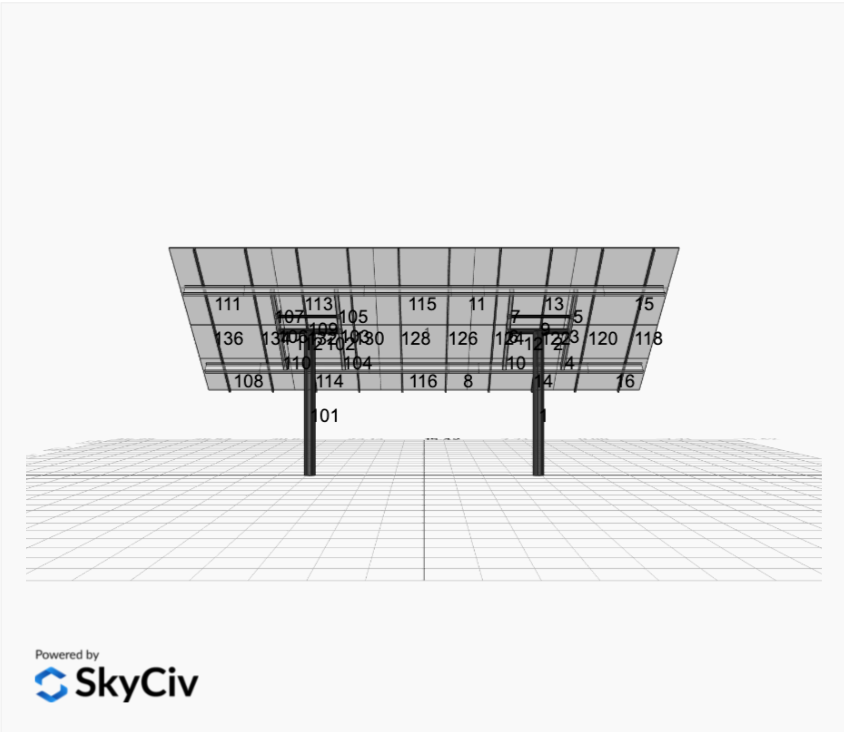
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105
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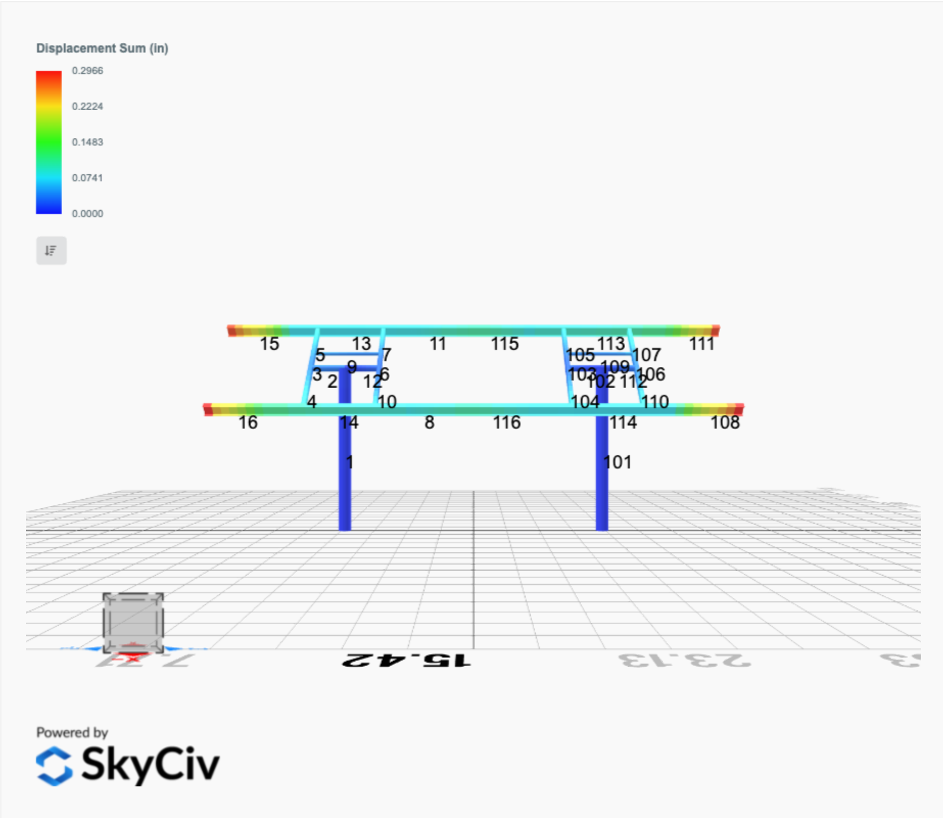
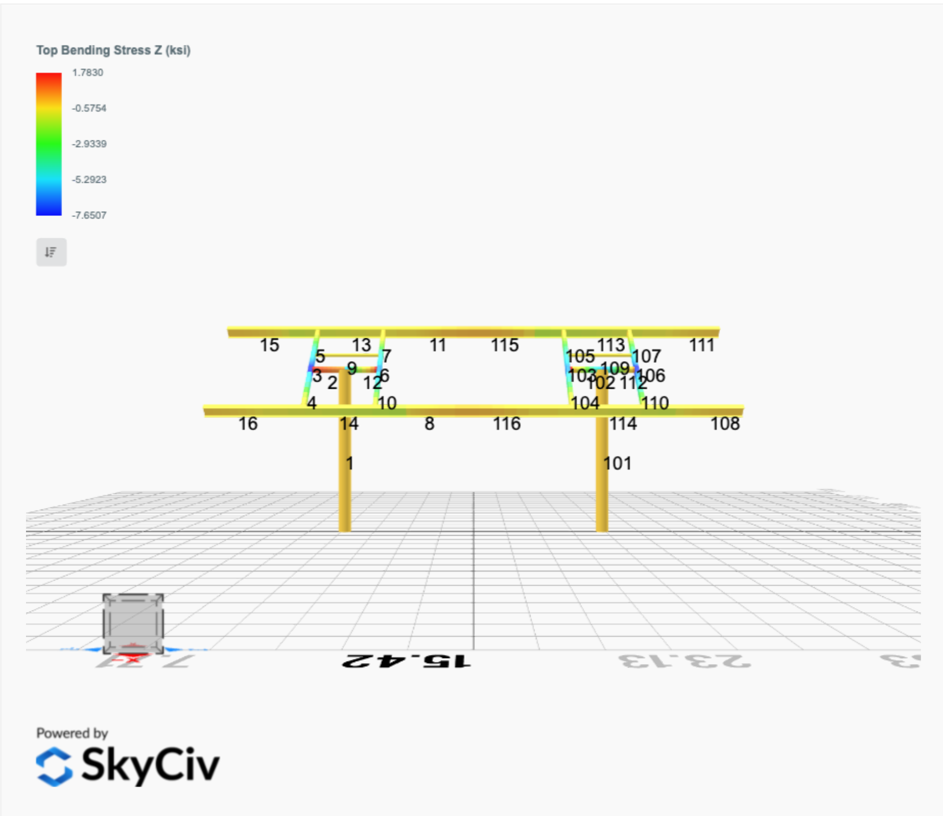
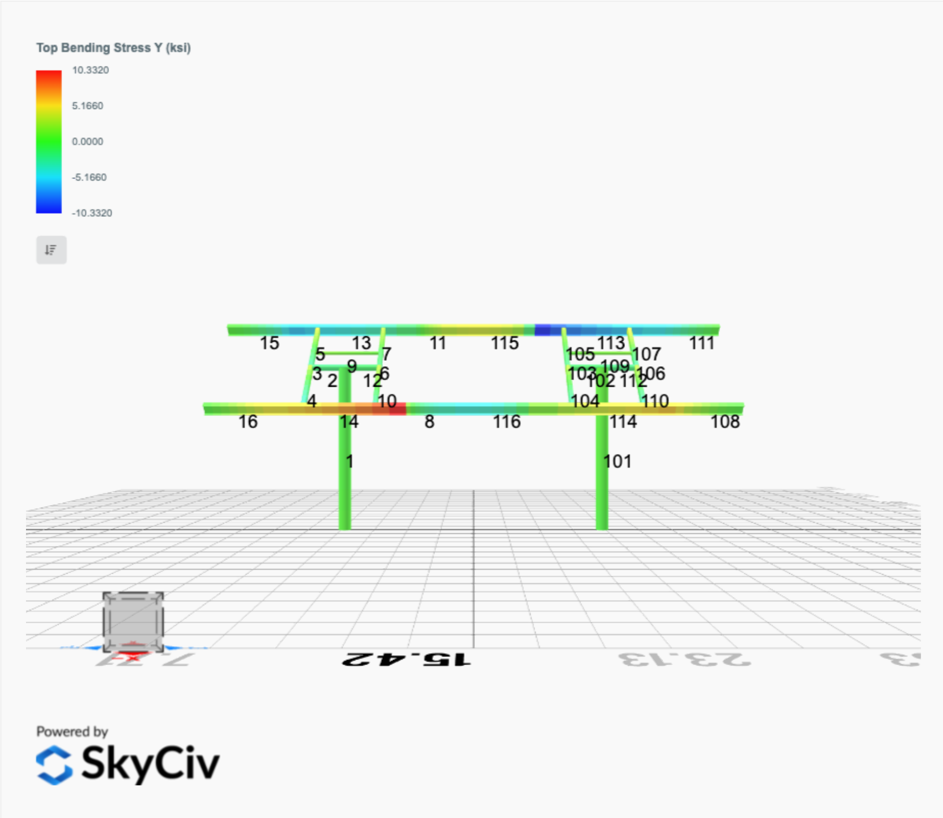
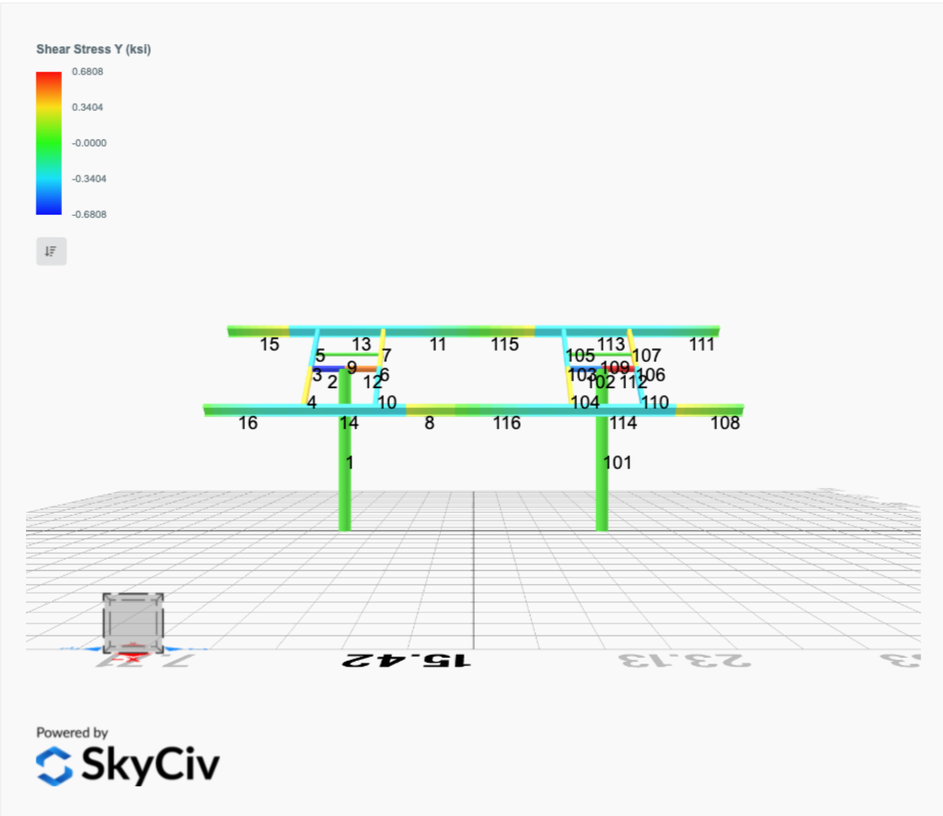
5
136
128
126
120
118
110
104
10
4
108
114
116
8
14
16
101
1
Powered by
SkyCiv

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




Top Bending Stress Y (ksi)
10.3320
5.1660
0.0000
-5.1660
-10.3320
Powered by
SkyCiv


Shear Stress Y (ksi)
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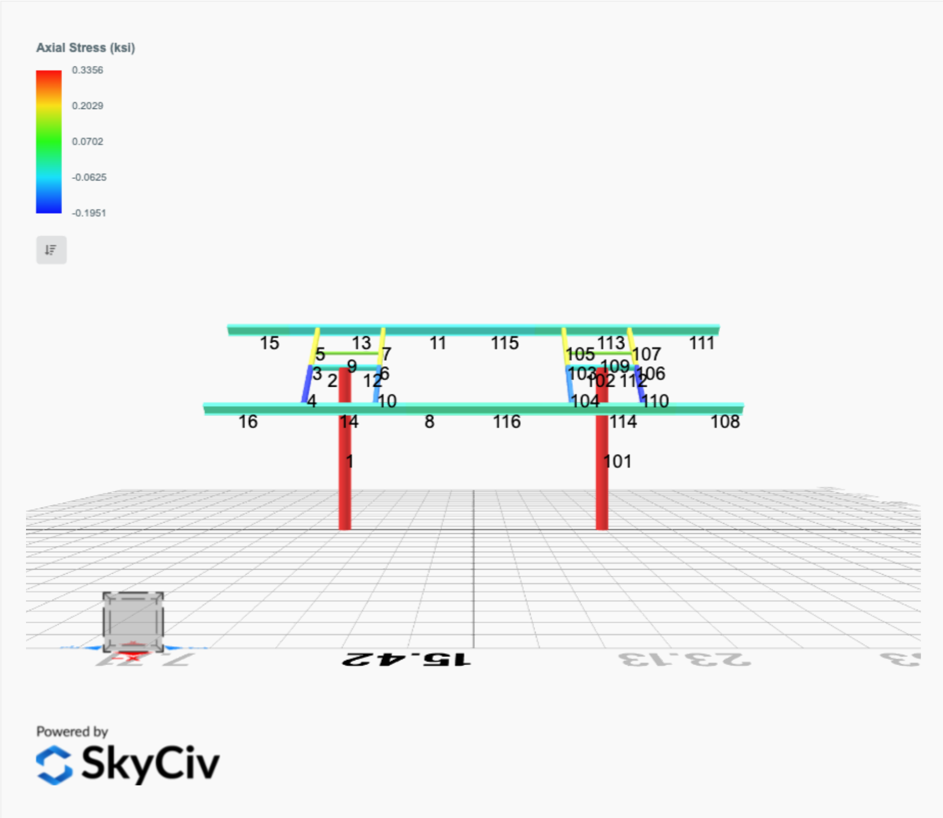
0.3404
-0.0000
-0.3404
-0.6808
Powered by
SkyCiv


Axial Stress (ksi)
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0.2029
0.0702
-0.0625
-0.1951
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
15.42
23.13
Powered by
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 | 0.0000 | 1.8009 | -0.0301 | -0.0735 | 0.0697 | 0.0234 |
| ULS: 2. D + L | 0.0000 | 1.8009 | -0.0301 | -0.0735 | 0.0697 | 0.0234 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 4.6195 | -0.0939 | -0.2296 | 0.2174 | 0.0335 |
| ULS: 3. D + (S or Lr or R) | 0.0000 | 1.8009 | -0.0301 | -0.0735 | 0.0697 | 0.0234 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 3.9149 | -0.0780 | -0.1906 | 0.1805 | 0.0310 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0000 | 1.8009 | -0.0301 | -0.0735 | 0.0697 | 0.0234 |
| ULS: 5b. D + 0.7E | 0.0000 | 1.8009 | -0.0301 | -0.0735 | 0.0697 | 0.0234 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0000 | 3.9149 | -0.0780 | -0.1906 | 0.1805 | 0.0310 |
| ULS: 8. 0.6D + 0.7E | 0.0000 | 1.0805 | -0.0180 | -0.0441 | 0.0418 | 0.0140 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.6972 | 5.0152 | -0.1403 | -0.3329 | 0.4269 | 26.4136 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.6972 | 5.0152 | -0.1403 | -0.3329 | 0.4269 | 26.4136 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.1496 | -0.7609 | 0.0575 | 0.1322 | -0.2148 | -19.8958 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 1.8251 | -0.3742 | 0.0448 | 0.1024 | -0.1735 | -23.1942 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.0229 | 6.3256 | -0.1607 | -0.3851 | 0.4484 | 19.8237 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.0229 | 6.3256 | -0.1607 | -0.3851 | 0.4484 | 19.8237 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6122 | 1.9935 | -0.0123 | -0.0363 | -0.0329 | -14.9084 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3689 | 2.2835 | -0.0218 | -0.0587 | -0.0019 | -17.3822 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.0229 | 4.2117 | -0.1128 | -0.2681 | 0.3376 | 19.8161 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.0229 | 4.2117 | -0.1128 | -0.2681 | 0.3376 | 19.8161 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6122 | -0.1205 | 0.0356 | 0.0808 | -0.1437 | -14.9160 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3689 | 0.1696 | 0.0261 | 0.0584 | -0.1127 | -17.3898 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.6972 | 4.2949 | -0.1283 | -0.3035 | 0.3990 | 26.4043 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.6972 | 4.2949 | -0.1283 | -0.3035 | 0.3990 | 26.4043 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.1496 | -1.4813 | 0.0695 | 0.1616 | -0.2427 | -19.9052 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 1.8251 | -1.0946 | 0.0568 | 0.1318 | -0.2013 | -23.2035 |

### 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 |
|---|---|
| Axial | 9.3495 |
| Shear X | -4.4953 |
| Shear Z | -0.2520 |
| Moment X | -0.5993 |
| Moment Z | 44.3919 |

### 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 |
|---|---|
| Axial | 6.3256 |
| Shear X | -2.6972 |
| Shear Z | -0.1607 |
| Moment X | -0.3851 |
| Moment Z | 26.4136 |

## 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 | -0.0000 | 1.8009 | 0.0301 | 0.0735 | -0.0697 | 0.0234 |
| ULS: 2. D + L | -0.0000 | 1.8009 | 0.0301 | 0.0735 | -0.0697 | 0.0234 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 4.6195 | 0.0939 | 0.2296 | -0.2174 | 0.0335 |
| ULS: 3. D + (S or Lr or R) | -0.0000 | 1.8009 | 0.0301 | 0.0735 | -0.0697 | 0.0234 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 3.9149 | 0.0780 | 0.1906 | -0.1805 | 0.0310 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0000 | 1.8009 | 0.0301 | 0.0735 | -0.0697 | 0.0234 |
| ULS: 5b. D + 0.7E | -0.0000 | 1.8009 | 0.0301 | 0.0735 | -0.0697 | 0.0234 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0000 | 3.9149 | 0.0780 | 0.1906 | -0.1805 | 0.0310 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 8. 0.6D + 0.7E | -0.0000 | 1.0805 | 0.0180 | 0.0441 | -0.0418 | 0.0140 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.6972 | 5.0152 | 0.1403 | 0.3329 | -0.4269 | 26.4136 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -2.6972 | 5.0152 | 0.1403 | 0.3329 | -0.4269 | 26.4136 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.1496 | -0.7609 | -0.0575 | -0.1322 | 0.2148 | -19.8958 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 1.8251 | -0.3742 | -0.0448 | -0.1024 | 0.1735 | -23.1942 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.0229 | 6.3256 | 0.1607 | 0.3851 | -0.4484 | 19.8237 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.0229 | 6.3256 | 0.1607 | 0.3851 | -0.4484 | 19.8237 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6122 | 1.9935 | 0.0123 | 0.0363 | 0.0329 | -14.9084 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3689 | 2.2835 | 0.0218 | 0.0587 | 0.0019 | -17.3822 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.0229 | 4.2117 | 0.1128 | 0.2681 | -0.3376 | 19.8161 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -2.0229 | 4.2117 | 0.1128 | 0.2681 | -0.3376 | 19.8161 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6122 | -0.1205 | -0.0356 | -0.0808 | 0.1437 | -14.9160 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 1.3689 | 0.1696 | -0.0261 | -0.0584 | 0.1127 | -17.3898 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.6972 | 4.2949 | 0.1283 | 0.3035 | -0.3990 | 26.4043 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -2.6972 | 4.2949 | 0.1283 | 0.3035 | -0.3990 | 26.4043 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.1496 | -1.4813 | -0.0695 | -0.1616 | 0.2427 | -19.9052 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 1.8251 | -1.0946 | -0.0568 | -0.1318 | 0.2013 | -23.2035 |

### 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 |
|---|---|
| Axial | 9.3495 |
| Shear X | -4.4953 |
| Shear Z | 0.2520 |
| Moment X | 0.5994 |
| Moment Z | 44.3926 |

### 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 |
|---|---|
| Axial | 6.3256 |
| Shear X | -2.6972 |
| Shear Z | 0.1607 |
| Moment X | 0.3851 |
| Moment Z | 26.4136 |

# Project Details

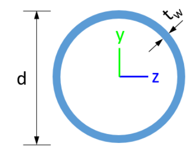
| | |
|---|---|
| Design Code: | AISC 360-16 LRFD |
| Provision: | LRFD |
| Country: | United States |
| User Name: | sales@mtsolar.us |
| Project Name: | Simmons_18mods |
| Unit System: | imperial |

# Design Input Information

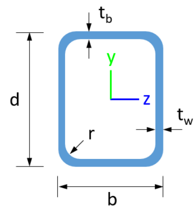
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

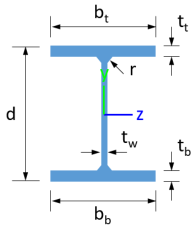
**Section Dimensions**




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




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




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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | 8in Pipe Sch 40 | 8.40 | 144.98 | 72.49 | 72.49 | 0.00 | 22.21 | 22.21 |
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 92.39 | 2.96 | 4.21 |
| 19 | W8x10 | 2.96 | 0.04 | 2.09 | 30.80 | 30.90 | 1.66 | 8.87 |

**Member Properties**

| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$ (ft) | $C_b$ | LST | LSC | LD |
|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 19.86 | 19.86 | 9.46 | - | 300 | 200 | 1 |
| 2 | 5 | 0.25 | 0.25 | 0.25 | - | 300 | 200 | 1 |
| 3 | 16 | 1.42 | 1.42 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 4 | 16 | 3.75 | 3.75 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.80,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.68,1.67,1.67,1.65,1.80,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 5 | 16 | 2.33 | 2.33 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 16 | 1.42 | 1.42 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 7 | 16 | 2.33 | 2.33 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 8 | 19 | 2.05 | 2.05 | 2.05 | 2.37,2.37,2.37,2.37,2.37,2.37,2.36,2.36,2.35,1.99,2.36,2.36,2.35,2.31,2.36,2.36,2.39,2.38,2.36,2.36,2.35,2.20,2.36,2.36,2.35,2.33 | 300 | 200 | 1 |
| 9 | 2 | 4.00 | 4.00 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 3.75 | 3.75 | 3.75 | 1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.74,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.68,1.67,1.67,1.65,1.77,1.67,1.67,1.66,1.64 | 300 | 200 | 1 |
| 11 | 19 | 2.05 | 2.05 | 2.05 | 2.38,2.37,2.38,2.37,2.38,2.38,2.37,2.37,2.35,2.36,2.36,2.36,2.36,2.36,2.37,2.37,2.39,2.41,2.37,2.37,2.35,2.36,2.36,2.36,2.36,2.37 | 300 | 200 | 1 |
| 12 | 5 | 2.00 | 2.00 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 1.75 | 1.75 | 1.75 | 1.41,1.41,1.41,1.41,1.41,1.41,1.41,1.41,1.40,1.40,1.41,1.41,1.40,1.41,1.41,1.41,1.41,1.42,1.41,1.41,1.40,1.40,1.41,1.41,1.40,1.41 | 300 | 200 | 1 |
| 14 | 19 | 1.75 | 1.75 | 1.75 | 1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30 | 300 | 200 | 1 |
| 15 | 19 | 3.75 | 3.75 | 3.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 19 | 3.75 | 3.75 | 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 |
| 17 | 19 | 4.00 | 4.00 | 4.00 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16 | 300 | 200 | 1 |
| 18 | 19 | 1.75 | 1.75 | 1.75 | 1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30 | 300 | 200 | 1 |
| 19 | 19 | 4.00 | 4.00 | 4.00 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.30,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.16,2.83,1.16,1.16,1.16,1.17 | 300 | 200 | 1 |
| 20 | 19 | 1.75 | 1.75 | 1.75 | 1.41,1.41,1.41,1.41,1.41,1.41,1.40,1.40,1.40,1.48,1.40,1.40,1.40,1.39,1.40,1.40,1.41,1.41,1.40,1.40,1.40,1.46,1.40,1.40,1.40,1.39 | 300 | 200 | 1 |
| 21 | 19 | 4.00 | 4.00 | 4.00 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16 | 300 | 200 | 1 |
| 22 | 19 | 1.75 | 1.75 | 1.75 | 1.41,1.41,1.41,1.41,1.41,1.41,1.41,1.41,1.40,1.40,1.41,1.41,1.40,1.41,1.41,1.41,1.41,1.42,1.41,1.41,1.40,1.40,1.41,1.41,1.40,1.41 | 300 | 200 | 1 |
| 23 | 19 | 4.00 | 4.00 | 4.00 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.32,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.16,2.82,1.16,1.16,1.16,1.18 | 30 | 20 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | [illegible] | 0 | 0 | |
| 24 | 19 | 1.75 | 1.75 | 1.75 | 1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30 | 300 | 200 | 1 |
| 25 | 5 | 1.75 | 1.75 | 1.75 | - | 300 | 200 | 1 |
| 26 | 5 | 0.25 | 0.25 | 0.25 | - | 300 | 200 | 1 |
| 101 | 9 | 19.86 | 19.86 | 9.46 | - | 300 | 200 | 1 |
| 102 | 5 | 2.00 | 2.00 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 1.42 | 1.42 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 104 | 16 | 3.75 | 3.75 | 3.75 | 1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.66,1.74,1.67,1.67,1.66,1.62,1.67,1.67,1.68,1.68,1.67,1.67,1.65,1.77,1.67,1.67,1.66,1.64 | 300 | 200 | 1 |
| 105 | 16 | 2.33 | 2.33 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 106 | 16 | 1.42 | 1.42 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 107 | 16 | 2.33 | 2.33 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 108 | 19 | 3.75 | 3.75 | 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 |
| 109 | 2 | 4.00 | 4.00 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 3.75 | 3.75 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.80,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.68,1.67,1.67,1.65,1.80,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 111 | 19 | 3.75 | 3.75 | 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 |
| 112 | 5 | 1.75 | 1.75 | 1.75 | - | 300 | 200 | 1 |
| 113 | 19 | 1.75 | 1.75 | 1.75 | 1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30 | 300 | 200 | 1 |
| 114 | 19 | 1.75 | 1.75 | 1.75 | 1.41,1.41,1.41,1.41,1.41,1.41,1.40,1.40,1.40,1.48,1.40,1.40,1.40,1.39,1.40,1.40,1.41,1.41,1.40,1.40,1.40,1.46,1.40,1.40,1.40,1.39 | 300 | 200 | 1 |
| 115 | 19 | 5.45 | 5.45 | 5.45 | 1.65,1.66,1.65,1.66,1.66,1.65,1.72,1.72,1.80,1.74,1.72,1.72,1.77,1.72,1.70,1.70,1.56,1.49,1.71,1.71,1.81,1.74,1.72,1.72,1.76,1.72 | 300 | 200 | 1 |
| 116 | 19 | 5.45 | 5.45 | 5.45 | 1.68,1.69,1.68,1.70,1.69,1.68,1.76,1.76,1.83,1.24,1.77,1.77,1.80,2.02,1.74,1.74,1.59,1.65,1.76,1.76,1.84,1.27,1.77,1.77,1.79,1.94 | 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 | 377.97 | 233.61 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 198.33 | 198.27 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 114.47 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 105.13 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 111.72 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 114.47 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 111.72 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 122.14 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 49.90 | 3.82 | 3.82 | 19.94 | 19.94 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | 116.10 | 105.13 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 122.14 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 194.54 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 107.59 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 107.59 | 32.87 | 6.12 | 40.24 | 43.62 |
| 17 | 133.20 | 104.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 18 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 19 | 133.20 | 104.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 20 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 21 | 133.20 | 104.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 22 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 23 | 133.20 | 104.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 24 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 25 | 198.33 | 195.42 | 21.95 | 21.95 | 59.50 | 59.50 |
| 26 | 198.33 | 198.27 | 21.95 | 21.95 | 59.50 | 59.50 |
| 101 | 377.97 | 233.61 | 83.29 | 83.29 | 113.39 | 113.39 |
| 102 | 198.33 | 194.54 | 21.95 | 21.95 | 59.50 | 59.50 |
| 103 | 116.10 | 114.47 | 15.79 | 11.10 | 42.08 | 23.28 |
| 104 | 116.10 | 105.13 | 15.79 | 11.10 | 42.08 | 23.28 |
| 105 | 116.10 | 111.72 | 15.79 | 11.10 | 42.08 | 23.28 |
| 106 | 116.10 | 114.47 | 15.79 | 11.10 | 42.08 | 23.28 |
| 107 | 116.10 | 111.72 | 15.79 | 11.10 | 42.08 | 23.28 |
| 108 | 133.20 | 107.59 | 32.87 | 6.12 | 40.24 | 43.62 |
| 109 | 66.48 | 49.90 | 3.82 | 3.82 | 19.94 | 19.94 |
| 110 | 116.10 | 105.13 | 15.79 | 11.10 | 42.08 | 23.28 |
| 111 | 133.20 | 107.59 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 195.42 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 123.94 | 32.87 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 85.54 | 32.87 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 85.54 | 32.87 | 6.12 | 40.24 | 43.62 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.040 | 0.533 | 0.021 | 0.040 | 0.002 | 0.559 | #13 | 0.406 | Not Required | Pass |
| 2 | 0.001 | 0.074 | 0.055 | 0.081 | 0.040 | 0.113 | #23 | 0.010 | Not Required | Pass |
| 3 | 0.009 | 0.614 | 0.076 | 0.062 | 0.019 | 0.659 | #13 | 0.070 | Not Required | Pass |
| 4 | 0.010 | 0.580 | 0.124 | 0.058 | 0.026 | 0.608 | #13 | 0.123 | Not Required | Pass |
| 5 | 0.010 | 0.380 | 0.130 | 0.061 | 0.032 | 0.396 | #13 | 0.115 | Not Required | Pass |
| 6 | 0.008 | 0.534 | 0.052 | 0.053 | 0.010 | 0.557 | #13 | 0.070 | Not Required | Pass |
| 7 | 0.008 | 0.331 | 0.088 | 0.053 | 0.022 | 0.340 | #13 | 0.115 | Not Required | Pass |
| 8 | 0.001 | 0.037 | 0.088 | 0.028 | 0.011 | 0.100 | #21 | 0.146 | Not Required | Pass |
| 9 | 0.006 | 0.054 | 0.055 | 0.002 | 0.002 | 0.111 | #13 | 0.313 | Not Required | Pass |
| 10 | 0.008 | 0.501 | 0.099 | 0.050 | 0.024 | 0.557 | #13 | 0.123 | Not Required | Pass |
| 11 | 0.002 | 0.039 | 0.089 | 0.030 | 0.011 | 0.103 | #21 | 0.098 | Not Required | Pass |
| 12 | 0.002 | 0.295 | 0.185 | 0.070 | 0.035 | 0.476 | #13 | 0.081 | Not Required | Pass |
| 13 | 0.002 | 0.117 | 0.204 | 0.044 | 0.016 | 0.305 | #21 | 0.083 | Not Required | Pass |
| 14 | 0.000 | 0.138 | 0.323 | 0.041 | 0.016 | 0.446 | #21 | Not Required | Not Required | Pass |
| 15 | 0.000 | 0.068 | 0.150 | 0.030 | 0.011 | 0.209 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.064 | 0.150 | 0.028 | 0.011 | 0.207 | #21 | Not Required | Not Required | Pass |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 0.006 | 0.153 | 0.089 | 0.020 | 0.008 | 0.222 | #21 | 0.190 | Not Required | Pass |
| 18 | 0.000 | 0.146 | 0.323 | 0.044 | 0.016 | 0.450 | #21 | Not Required | Not Required | Pass |
| 19 | 0.006 | 0.149 | 0.114 | 0.019 | 0.009 | 0.249 | #21 | 0.286 | Not Required | Pass |
| 20 | 0.001 | 0.111 | 0.204 | 0.041 | 0.016 | 0.303 | #21 | 0.125 | Not Required | Pass |
| 21 | 0.006 | 0.153 | 0.089 | 0.020 | 0.008 | 0.222 | #21 | 0.190 | Not Required | Pass |
| 22 | 0.002 | 0.117 | 0.204 | 0.044 | 0.016 | 0.305 | #21 | 0.083 | Not Required | Pass |
| 23 | 0.006 | 0.149 | 0.114 | 0.019 | 0.009 | 0.249 | #21 | 0.286 | Not Required | Pass |
| 24 | 0.000 | 0.138 | 0.323 | 0.041 | 0.016 | 0.446 | #21 | Not Required | Not Required | Pass |
| 25 | 0.001 | 0.371 | 0.219 | 0.082 | 0.040 | 0.591 | #13 | 0.071 | Not Required | Pass |
| 26 | 0.001 | 0.074 | 0.055 | 0.081 | 0.040 | 0.113 | #23 | 0.010 | Not Required | Pass |
| 101 | 0.040 | 0.533 | 0.021 | 0.040 | 0.002 | 0.559 | #13 | 0.406 | Not Required | Pass |
| 102 | 0.002 | 0.295 | 0.185 | 0.070 | 0.035 | 0.476 | #13 | 0.081 | Not Required | Pass |
| 103 | 0.008 | 0.534 | 0.052 | 0.053 | 0.010 | 0.557 | #13 | 0.070 | Not Required | Pass |
| 104 | 0.008 | 0.501 | 0.099 | 0.050 | 0.024 | 0.557 | #13 | 0.123 | Not Required | Pass |
| 105 | 0.008 | 0.331 | 0.088 | 0.053 | 0.022 | 0.340 | #13 | 0.115 | Not Required | Pass |
| 106 | 0.009 | 0.614 | 0.076 | 0.062 | 0.019 | 0.659 | #13 | 0.070 | Not Required | Pass |
| 107 | 0.010 | 0.380 | 0.130 | 0.061 | 0.032 | 0.396 | #13 | 0.115 | Not Required | Pass |
| 108 | 0.000 | 0.064 | 0.150 | 0.028 | 0.011 | 0.207 | #21 | Not Required | Not Required | Pass |
| 109 | 0.006 | 0.054 | 0.055 | 0.002 | 0.002 | 0.111 | #13 | 0.313 | Not Required | Pass |
| 110 | 0.010 | 0.580 | 0.124 | 0.058 | 0.026 | 0.608 | #13 | 0.123 | Not Required | Pass |
| 111 | 0.000 | 0.068 | 0.150 | 0.030 | 0.011 | 0.209 | #21 | Not Required | Not Required | Pass |
| 112 | 0.001 | 0.371 | 0.219 | 0.082 | 0.040 | 0.591 | #13 | 0.071 | Not Required | Pass |
| 113 | 0.000 | 0.146 | 0.323 | 0.044 | 0.016 | 0.450 | #21 | Not Required | Not Required | Pass |
| 114 | 0.001 | 0.111 | 0.204 | 0.041 | 0.016 | 0.303 | #21 | 0.125 | Not Required | Pass |
| 115 | 0.002 | 0.039 | 0.118 | 0.030 | 0.011 | 0.144 | #21 | 0.259 | Not Required | Pass |
| 116 | 0.002 | 0.037 | 0.118 | 0.028 | 0.011 | 0.141 | #21 | 0.389 | Not Required | Pass |

## Definitions

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

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

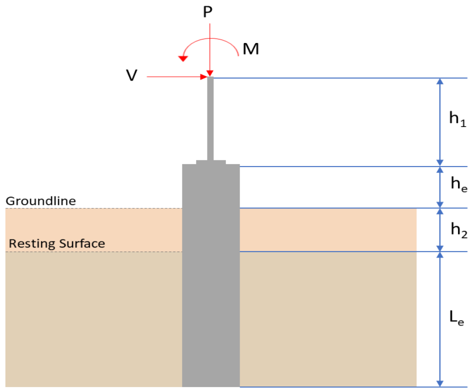
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.326 | 9.350 |
| $V_x$ (kip) | -2.697 | -4.495 |
| $V_z$ (kip) | -0.161 | -0.252 |
| $M_x$ (kipft) | -0.385 | -0.599 |
| $M_z$ (kipft) | 26.414 | 44.392 |

**Material Properties**

$f'_{ck} = 3$ ksi - Concrete strength,

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.697\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.42946\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(26.414\ \mathrm{kipft}) + ((-2.697\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 4.2061\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.7357\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.161\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.025637\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.385\ \mathrm{kipft}) + ((-0.161\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.061306\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.4009\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(5.7357\ \mathrm{ft}), (1.4009\ \mathrm{ft})]$$

$$L_{e,req} = 5.736\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 6.25\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.736\ \mathrm{ft})}{(6.25\ \mathrm{ft})}$$

$$Ratio = 0.91776$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\,D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(6.326\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.39537\ \mathrm{kip/ft}^2$$

$q = 0.39537\ \mathrm{kip/ft}$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.39537\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.19769$$

Status: **PASS**
Ratio: **0.200**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.42946\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.2061\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2061\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.42946\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (4.2061\ \mathrm{kipft/ft})) + (4 \times (-0.42946\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.3221\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2061\ \mathrm{kipft/ft})) + (3 \times (-0.42946\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (4.2061\ \mathrm{kipft/ft})) + (2 \times (-0.42946\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.20378\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (4.2061\ \mathrm{kipft/ft})) + ((-0.42946\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.87982\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.3221\ \mathrm{ft})}{2}$$

$$p_a = 0.32416\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20378\ \mathrm{kip/ft^2}\right)}{\left(0.32416\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.62863$$

Status: **PASS**
Ratio: **0.630**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.87982\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93847$$

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

**Considering z-direction:**

$H_o = -0.025637\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.061306\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.061306\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.061306\ \mathrm{kipft/ft})) + (4 \times (-0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4976\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.061306\ \mathrm{kipft/ft})) + (3 \times (-0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.061306\ \mathrm{kipft/ft})) + (2 \times (-0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = -0.0077965\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.061306\ \mathrm{kipft/ft})) + ((-0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = -0.0057783\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4976\ \mathrm{ft})}{2}$$

$$p_a = 0.33732\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0077965\ \mathrm{kip/ft^2}\right)}{\left(0.33732\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.023113$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

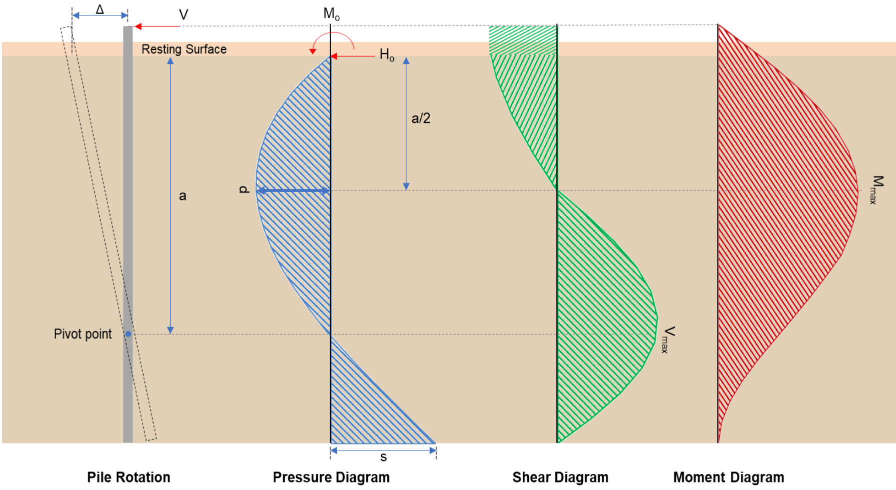
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0057783\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.0061636$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.495\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.71576\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(44.392\ \mathrm{kipft}) + ((-4.495\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 7.0688\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(7.0688\ \mathrm{kipft/ft})}{(-0.71576\ \mathrm{kip/ft})}$$

$$E = 9.8759\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (7.0688\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.71576\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (7.0688\ \mathrm{kipft/ft})) + (4 \times (-0.71576\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.3212\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.71576\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.8759\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.3212\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.8759\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.3212\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8932\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.71576\text{ kip/ft})\times(48\text{ in})\times(6.25\text{ ft}))\times\left[\left(\frac{(9.8759\text{ ft})}{(6.25\text{ ft})}+\frac{(4.3212\text{ ft})}{2\times(6.25\text{ ft})}\right) - \left[\left(\frac{4\times(9.8759\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.3212\text{ ft})}{2\times(6.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(9.8759\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.3212\text{ ft})}{2\times(6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 29.293\text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.252\text{ kip})}{1.57\times(48\text{ in})}$$

$$H_o = -0.040127\text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.599\text{ kipft})+((-0.252\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.095382\text{ kipft/ft}$$

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

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

$$E = \frac{(0.095382\text{ kipft/ft})}{(-0.040127\text{ kip/ft})}$$

$$E = 2.377\text{ ft}$$

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

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

$$a = \frac{(4\times(0.095382\text{ kipft/ft})\times(6.25\text{ ft}))+\left(3\times(-0.040127\text{ kip/ft})\times(6.25\text{ ft})^2\right)}{(6\times(0.095382\text{ kipft/ft}))+(4\times(-0.040127\text{ kip/ft})\times(6.25\text{ ft}))}$$

$$a = 4.4983\text{ ft}$$

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

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

$$V_{max} = ((-0.040127\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(2.377\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.4983\text{ ft})}{(6.25\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(2.377\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.4983\text{ ft})}{(6.25\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21541\text{ kip}$$

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

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

$$M_{max} = ((-0.040127\text{ kip/ft})\times(48\text{ in})\times(6.25\text{ ft}))\times\left[\left(\frac{(2.377\text{ ft})}{(6.25\text{ ft})}+\frac{(4.4983\text{ ft})}{2\times(6.25\text{ ft})}\right) - \left[\left(\frac{4\times(2.377\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.4983\text{ ft})}{2\times(6.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(2.377\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.4983\text{ ft})}{2\times(6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.58401\text{ kipft}$$

**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* $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.35\text{ kip})}{(0.65)\times(0.8)} - \left(0.85\times(3\text{ ksi})\times\left(2304\text{ in}^2\right)\right)}{(60\text{ ksi}) - (0.85\times(3\text{ ksi}))}, \left(0.08\times\left(2304\text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.95\text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-101.95\text{ in}^2\right), \left(0.0018\times\left(2304\text{ in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

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

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

*22.4.2.2* $\phi P_N$ - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.35\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0029371$$

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

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

**Parameters:**

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

*22.5.2.2* $d$ - Effective depth

$$d = 0.80\, D$$

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

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

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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 324.49\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 9.35\ \text{kip} \rightarrow 9350\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(9350\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.04\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,b} = 406.27\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.04\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.04\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 807.65\ \text{kip}$$

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

$$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$

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

22.5.1.1 $\phi V_n$ - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.04\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.26\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 9.8932\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.8932\ \text{kip})}{(118.26\ \text{kip})}$$

$$Ratio = 0.083658$$

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

**Considering z-direction:**

$V_{max} = 0.21541\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21541\ \text{kip})}{(118.26\ \text{kip})}$$

$$Ratio = 0.0018216$$

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

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

$S_m$ - Section modulus

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

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

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

| | | |
|---|---|---|
| | $\lambda = 1$ - Concrete modification factor (Normal concrete),<br>Allowable flexural strength:<br>$M_n$ shall be the lesser of:<br>$\phi M_{n,1}$<br>$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$<br>$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$<br>$$\phi M_{n,1} = 273.423kipft$$ | |
| *14.5.2.1b* | $\phi M_{n,2}$<br>$$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$<br>$$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$<br>$$\phi M_{n,2} = 2545.9\text{ kipft}$$<br>Therefore,<br>$\phi M_n$ - Allowable flexural strength,<br>$$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$<br>$$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$<br>$$\phi M_n = 273.42\text{ kipft}$$<br>**Considering x-direction:**<br>$M_{max} = 29.293\text{ kipft}$ - Maximum moment in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(29.293\text{ kipft})}{(273.42\text{ kipft})}$$<br>$$Ratio = 0.10714$$ | Status: **PASS**<br>Ratio: **0.110** |
| | **Considering z-direction:**<br>$M_{max} = 0.58401\text{ kipft}$ - Maximum moment in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{M_{max}}{\phi M_n}$$<br>$$Ratio = \frac{(0.58401\text{ kipft})}{(273.42\text{ kipft})}$$<br>$$Ratio = 0.0021359$$ | Status: **PASS**<br>Ratio: **0.000** |

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

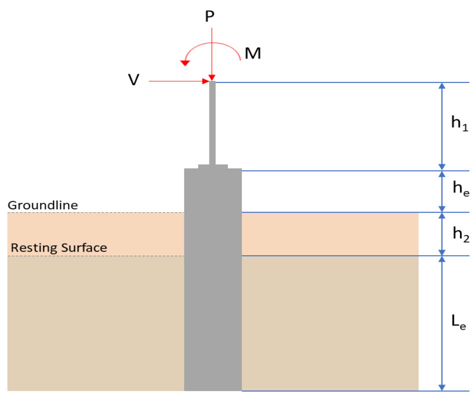
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

**Tabulation of Soil Parameters**

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

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.326 | 9.350 |
| $V_x$ (kip) | -2.697 | -4.495 |
| $V_z$ (kip) | 0.161 | 0.252 |
| $M_x$ (kipft) | 0.385 | 0.599 |
| $M_z$ (kipft) | 26.414 | 44.393 |

**Material Properties**

$f'_{ck} = 3$ ksi - Concrete strength,

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-2.697\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.42946\text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(26.414 \text{ kipft}) + ((-2.697 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2061 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.7357 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.161 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.025637 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.385 \text{ kipft}) + ((0.161 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.061306 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.9982 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(5.7357 \text{ ft}), (1.9982 \text{ ft})]$$

$$L_{e,req} = 5.736 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.736 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.91776$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(6.326 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.39537 \text{ kip/ft}^2$$

$q = 0.39537\ \text{kip/ft}$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39537\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.19769$$

Status: **PASS**
Ratio: **0.200**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.42946\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.2061\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2061\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.42946\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (4.2061\ \text{kipft/ft})) + (4 \times (-0.42946\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.3221\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2061\ \text{kipft/ft})) + (3 \times (-0.42946\ \text{kip/ft}) \times (6.25\ \text{ft}))]^{\ 2}}{(6.25\ \text{ft})^2 \times [(3 \times (4.2061\ \text{kipft/ft})) + (2 \times (-0.42946\ \text{kip/ft}) \times (6.25\ \text{ft}))]}$$

$$p = 0.20378\ \text{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.2061\ \text{kipft/ft})) + ((-0.42946\ \text{kip/ft}) \times (6.25\ \text{ft}))]}{(6.25\ \text{ft})^2}$$

$$s = 0.87982\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.3221\ \text{ft})}{2}$$

$$p_a = 0.32416\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.20378\ \text{kip/ft}^2)}{(0.32416\ \text{kip/ft}^2)}$$

$$Ratio = 0.62863$$

Status: **PASS**
Ratio: **0.630**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.87982\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.93847$$

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

**Considering z-direction:**

$H_o = 0.025637\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.061306\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.061306\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.061306\ \mathrm{kipft/ft})) + (4 \times (0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4976\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.061306\ \mathrm{kipft/ft})) + (3 \times (0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^{\ 2}}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.061306\ \mathrm{kipft/ft})) + (2 \times (0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.020059\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.061306\ \mathrm{kipft/ft})) + ((0.025637\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.043445\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4976\ \mathrm{ft})}{2}$$

$$p_a = 0.33732\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.020059\ \mathrm{kip/ft^2})}{(0.33732\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.059467$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

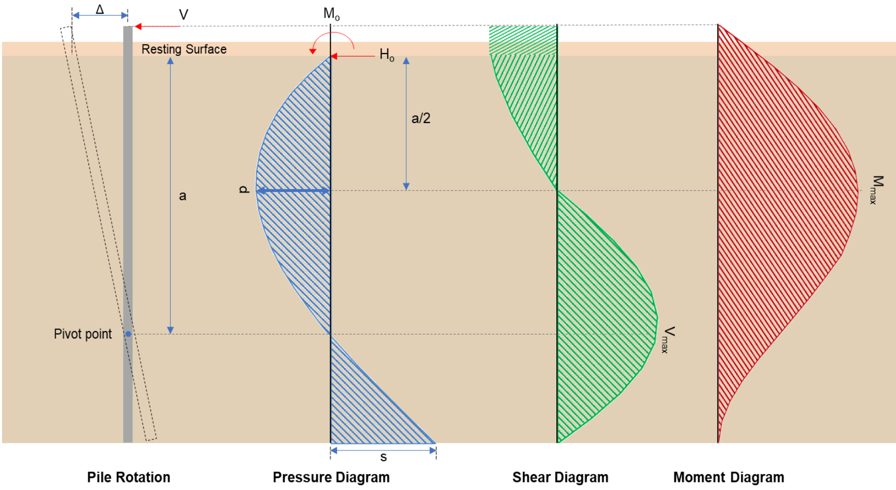
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.043445\ \text{kip/ft}^2)}{(0.9375\ \text{kip/ft}^2)}$$

$$Ratio = 0.046341$$

Status: **PASS**
Ratio: **0.050**




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.495\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.71576\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(44.393\ \text{kipft}) + ((-4.495\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.0689\ \text{kipft/ft}$$

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

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

$$E = \frac{(7.0689\ \text{kipft/ft})}{(-0.71576\ \text{kip/ft})}$$

$$E = 9.8761\ \text{ft}$$

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

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

$$a = \frac{(4 \times (7.0689\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.71576\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (7.0689\ \text{kipft/ft})) + (4 \times (-0.71576\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.3212\ \text{ft}$$

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

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

$$V_{max} = ((-0.71576\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.8761\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.3212\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.8761\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.3212\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.8933\ \text{kip}$$

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

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

$$M_{max} = ((-0.71576\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(9.8761\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.3212\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.8761\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.3212\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.8761\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.3212\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 29.294\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.252\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.040127\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.599\ \text{kipft}) + ((0.252\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.095382\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.095382\ \text{kipft/ft})}{(0.040127\ \text{kip/ft})}$$

$$E = 2.377\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.095382\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.040127\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.095382\ \text{kipft/ft})) + (4 \times (0.040127\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.4983\ \text{ft}$$

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

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

$$V_{max} = ((0.040127\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.377\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4983\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.377\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4983\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21541\ \text{kip}$$

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

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

$$M_{max} = ((0.040127\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(2.377\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.4983\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.377\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4983\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.377\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4983\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.58401 \text{ kipft}$$

**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* $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.35 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.95 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-101.95 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

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

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

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.35\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0029371$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 324.49\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 9.35\ \text{kip} \rightarrow 9350\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(9350\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.04\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,b} = 406.27\ \text{kip}$$

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.04\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.04\ \text{kip}$$

| | | |
|---|---|---|
| | 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)<br>$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$<br>$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$<br>$$V_{s,a} = 807.65\ \mathrm{kip}$$<br>$A_v$ - Ties rebar area,<br>$$A_v = \frac{\pi\, d_{ties}^2}{4}$$<br>$$A_v = \frac{\pi \times (0.375\ \mathrm{in})^2}{4}$$<br>$$A_v = 0.11045\ \mathrm{in}^2$$ | |
| *22.5.8.5.3* | $V_{s,b}$ - Shear strength of steel (b)<br>$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$<br>$$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (38.4\ \mathrm{in})}{(10\ \mathrm{in})}$$<br>$$V_{s,b} = 50.894\ \mathrm{kip}$$<br>$V_s$ - Governing shear strength of steel<br>$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$<br>$$V_s = MIN\left[(807.65\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$<br>$$V_s = 50.894\ \mathrm{kip}$$ | |
| *22.5.1.1* | $\phi V_n$ - Allowable shear strength<br>$$\phi V_n = \phi\ (V_c + V_s)$$<br>$$\phi V_n = (0.65) \times ((131.04\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$<br>$$\phi V_n = 118.26\ \mathrm{kip}$$<br>**Considering x-direction:**<br>$V_{max} = 9.8933\ \mathrm{kip}$ - Maximum shear force in the x-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{V_{max}}{\phi V_n}$$<br>$$Ratio = \frac{(9.8933\ \mathrm{kip})}{(118.26\ \mathrm{kip})}$$<br>$$Ratio = 0.083659$$ | Status: **PASS**<br>Ratio: **0.080** |
| | **Considering z-direction:**<br>$V_{max} = 0.21541\ \mathrm{kip}$ - Maximum shear force in the z-direction,<br>$Ratio$ - Capacity<br>$$Ratio = \frac{V_{max}}{\phi V_n}$$<br>$$Ratio = \frac{(0.21541\ \mathrm{kip})}{(118.26\ \mathrm{kip})}$$<br>$$Ratio = 0.0018216$$ | Status: **PASS**<br>Ratio: **0.000** |
| | **Flexural Strength (ACI 318-19, LRFD)**<br>$S_m$ - Section modulus<br>$$S_m = \frac{b\, D^2}{6}$$<br>$$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$<br>$$S_m = 18432\ \mathrm{in}^3$$ | |

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

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

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

$$\phi M_{n,1} = 273.423kipft$$

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

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

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

$$\phi M_{n,2} = 2545.9 \text{ kipft}$$

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

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

$$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$

$$\phi M_n = 273.42 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 29.294 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(29.294 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.10714$$

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

**Considering z-direction:**

$M_{max} = 0.58401 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.58401 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.0021359$$

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