# Project Details

**Project Name:** John Sweeney 5x11 - V1Jb

**Location:** 1502 Wood River Rd, Meeteetse, WY 82433, USA

**Unique ID:** 3P-22.5-8TOP-XD-57-L-5Hx11W-72K6

**Dealer:** ______________________________

**Date:** Wed Oct 01 2025

**Number of Modules:** 55

**Number of Poles:** 3

**Date Sold:**

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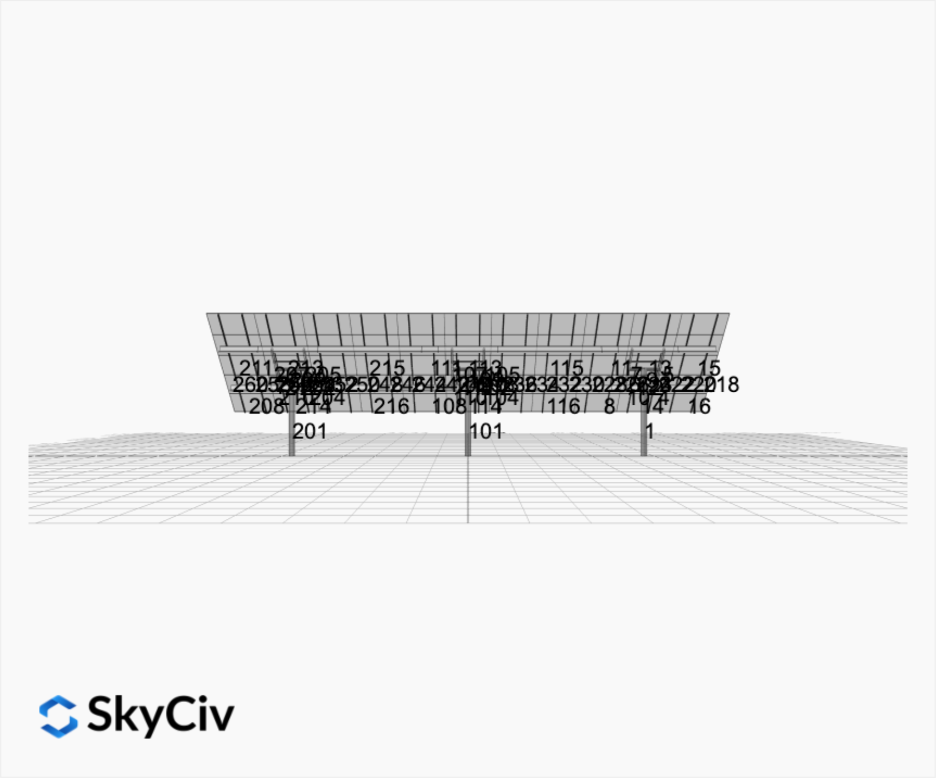


| | |
|---|---|
| **Array Dimensions N/S** | 18.96 ft |
| **Array Dimensions E/W** | 63.25 ft |
| **Winter Tilt Angle** | 40 |
| **Front Edge Clearance** | 5 ft |

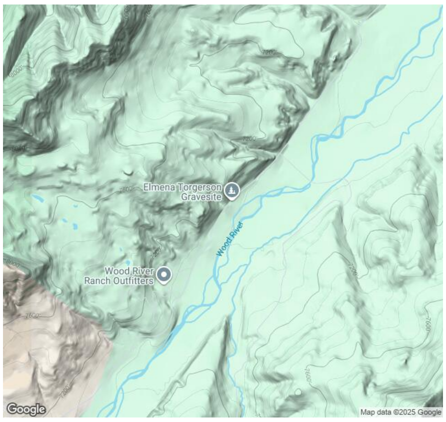
### MT Solar Bill of Materials (3P-22.5-8TOP-XD-57-L-5Hx11W-72K6)

| Part | Short Description | BOM Qty |
|---|---|---|
| MTS-PC-8 | 8IN Pole Cap Assembly | 3 |
| MTS-HF-XD | H-Frame Assembly-XD | 3 |
| MTS-XD-Wing-57 | 57IN XD Wing | 4 |
| MTS-XD-Splice-90 | 90IN XD Splice | 8 |
| MTS-CLAMP-ANGLE-4PK | Angle Clamp | 11 |

### Rail Bill of Materials

| Part | Qty |
|---|---|
| Rails (228in) | 22 |
| Rail Attachment | 88 |
| Module Mid Clamp | 88 |
| Module End Clamp | 44 |
| Ground Lug | 11 |

# Site Details:



**Site Address:** 1502 Wood River Rd, Meeteetse, WY 82433, USA

## Array Specification

| | |
|---|---|
| **Duty Classification:** | XD |
| **Module Width:** | 45.00 in |
| **Module Length:** | 68.00in |
| **Number of Rows:** | 5 |
| **Number of Columns:** | 11 |
| **Total Number of Modules:** | 55 |
| **Winter Tilt Angle:** | 40 |
| **Front Edge Clearance:** | 5 |
| **Total Array Height at Tilt:** | 17.19 ft |
| **Total Frame Length:** | 62.00 ft |
| **Module Info/Notes:** | JA 440w |
| **Array Dimensions N/S:** | 18.96 ft |
| **Array Dimensions E/W:** | 63.25 ft |
| **Rail Length:** | 227.50 in |
| **Rail Spacing:** | 2.88 ft |

## Support Specifications

| | |
|---|---|
| **Pole Size:** | 8in Pipe Sch 80 |
| **Pole Length above Grade:** | 11.09 ft |
| **Number of Poles:** | 3 |
| **Pole Spacing:** | 22.5 ft |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Square |
| **Foundation Dimensions:** | 48 x 48 in |
| **Foundation Depth (below grade):** | Pile 1: 7.75 ft<br>Pile 2: 8.00 ft<br>Pile 3: 7.75 ft |
| **Foundation Volume:** | 13.926 $y^3$ |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sand |
| **Site Location:** | 1502 Wood River Rd, Meeteetse, WY 82433, USA |
| **Wind Speed:** | 105 mph |
| **Snow Load:** | 45 psf |

## Design Disclaimer

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

## AutoDesigner Input

```
{"wind_speed_override":105,"snow_load_override":45,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Devin K","designer_email":"devin.king@cesolar.com","designer_phone":"3078511355","project_id":"John Sweeney 5x11 - V1Jb","site_address":"1502 Wood River Rd, Meeteetse, WY 82433, USA","module_info":"JA 440w","module_width":45,"module_length":68,"number_rows":"5","number_columns":11,"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","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}
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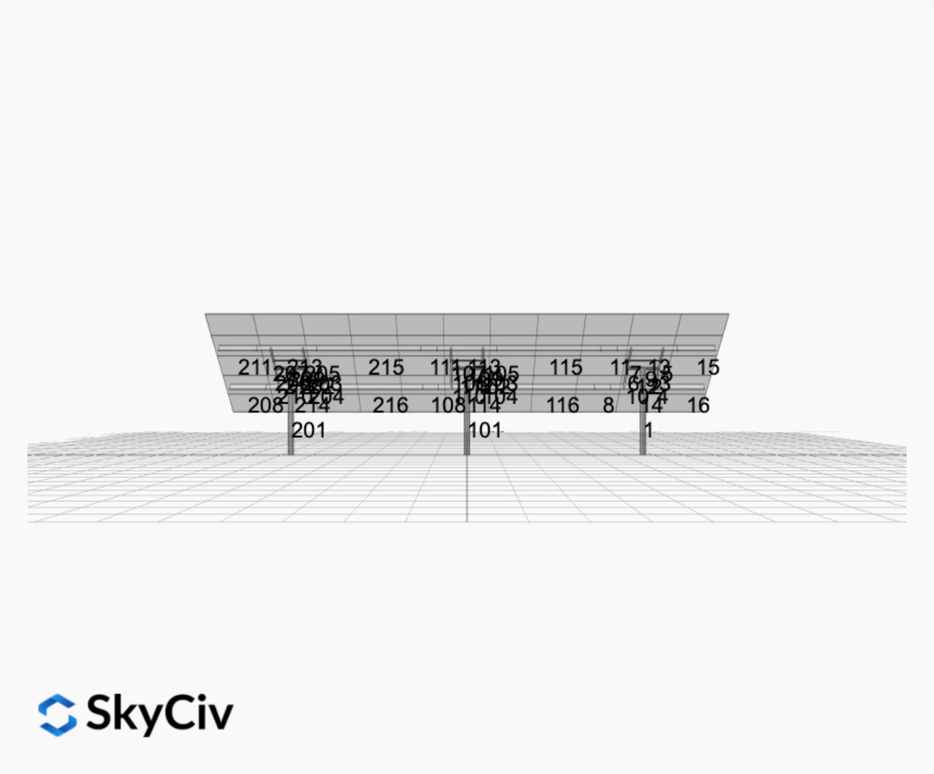
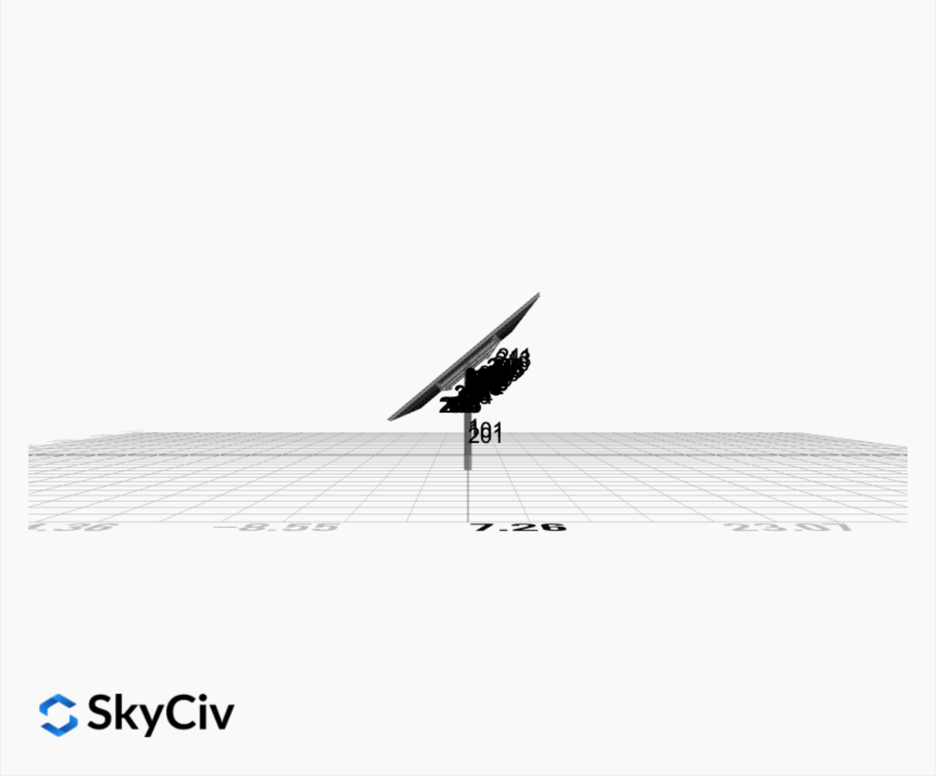
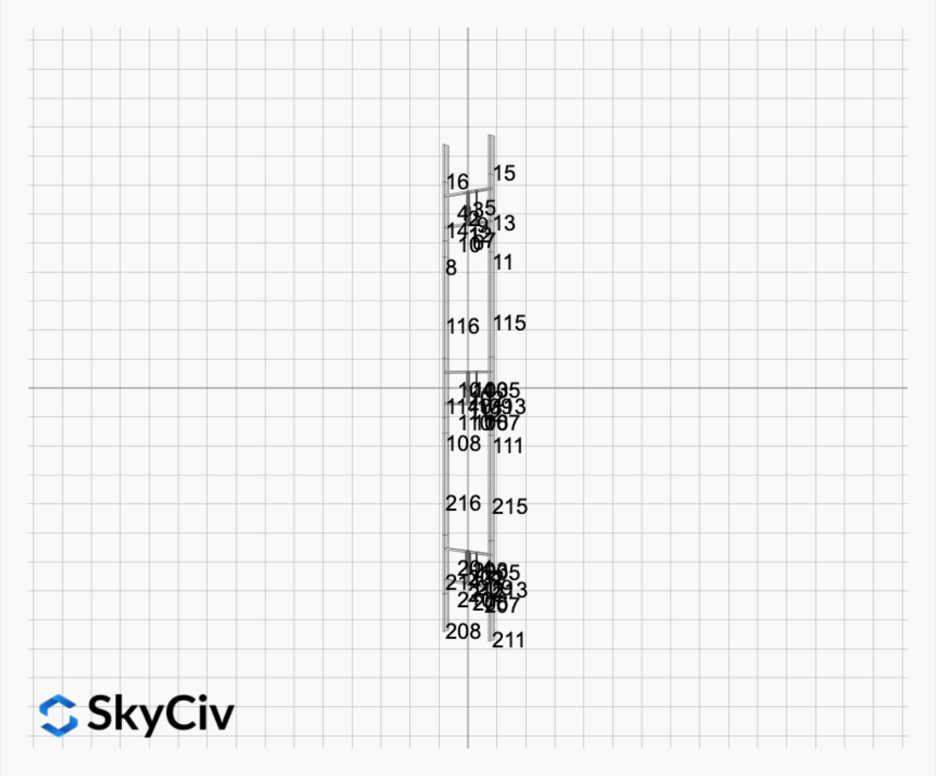
**Design Notes:**

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)




101
201
-8.55
7.26
23.01
SkyCiv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8
11
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115
108
111
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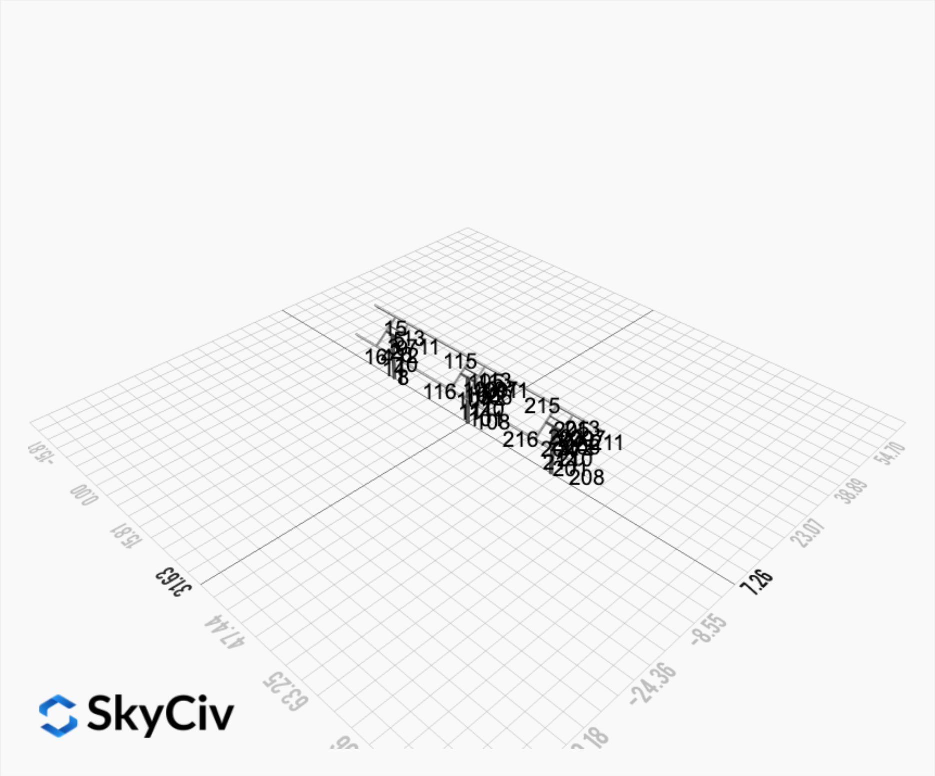
215
208
211
SkyCiv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11
16
8
115
116
215
216
208
-15.81
0.00
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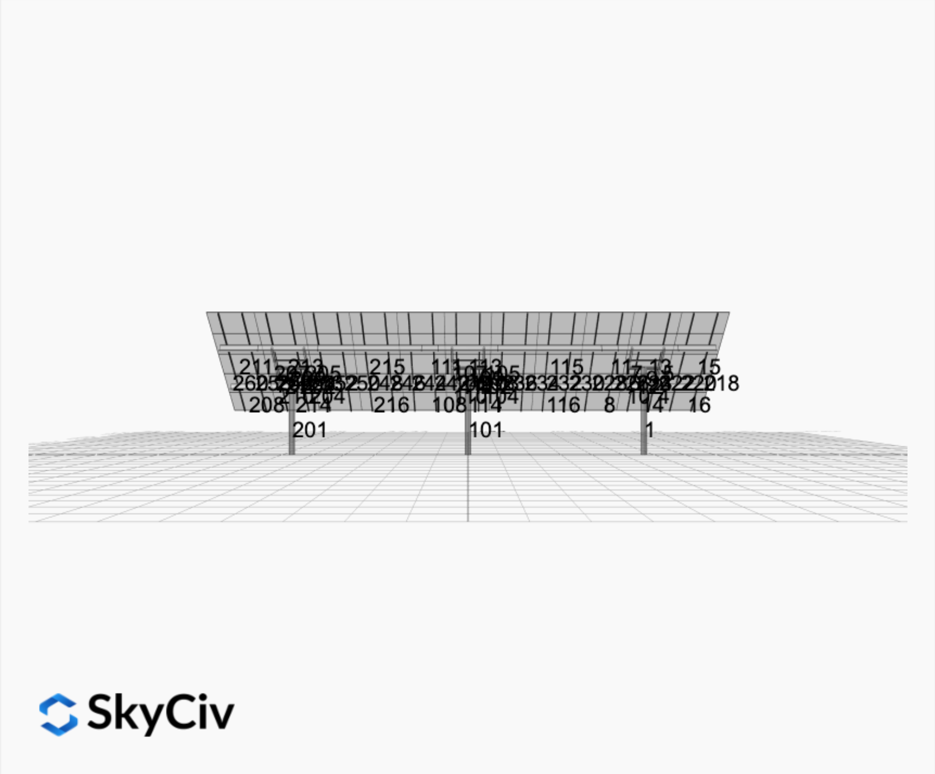
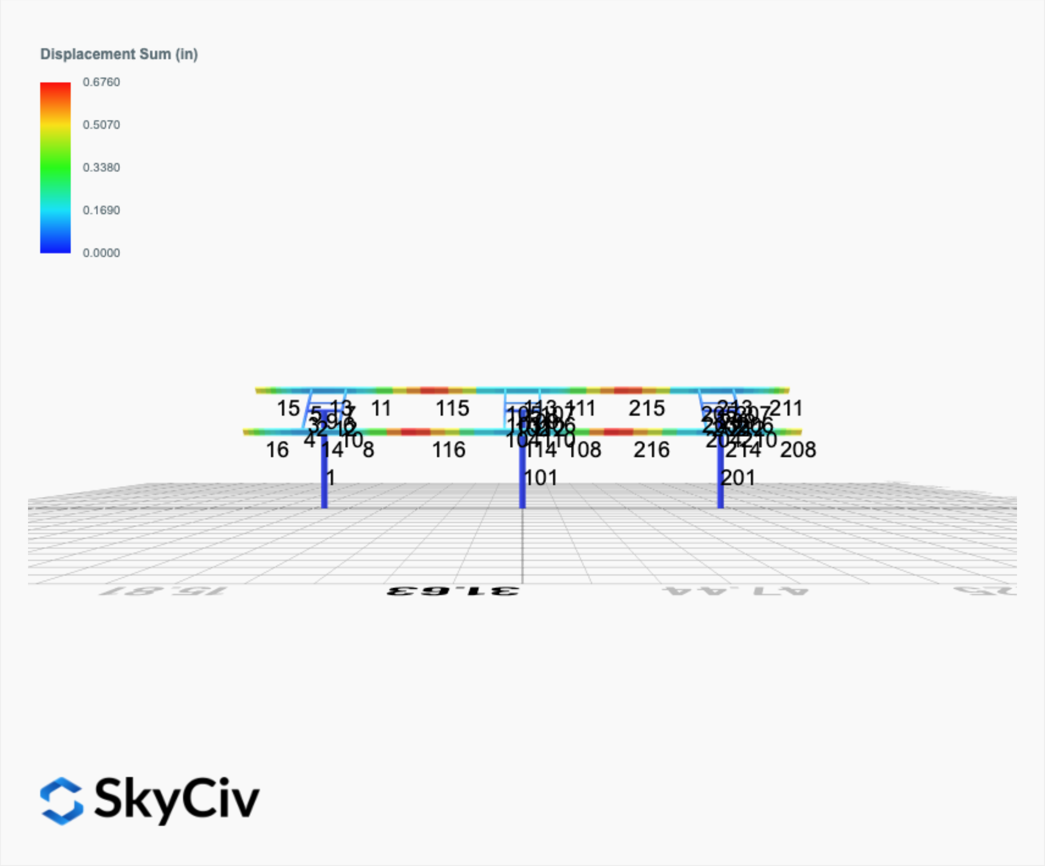
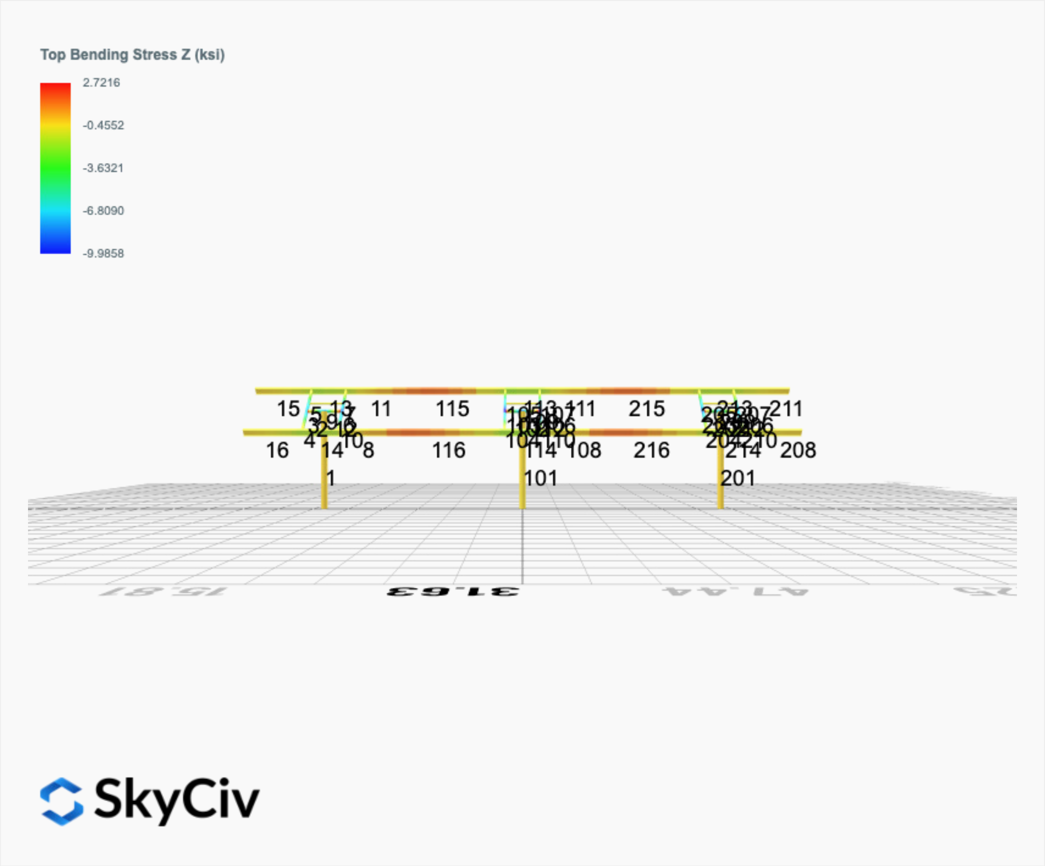
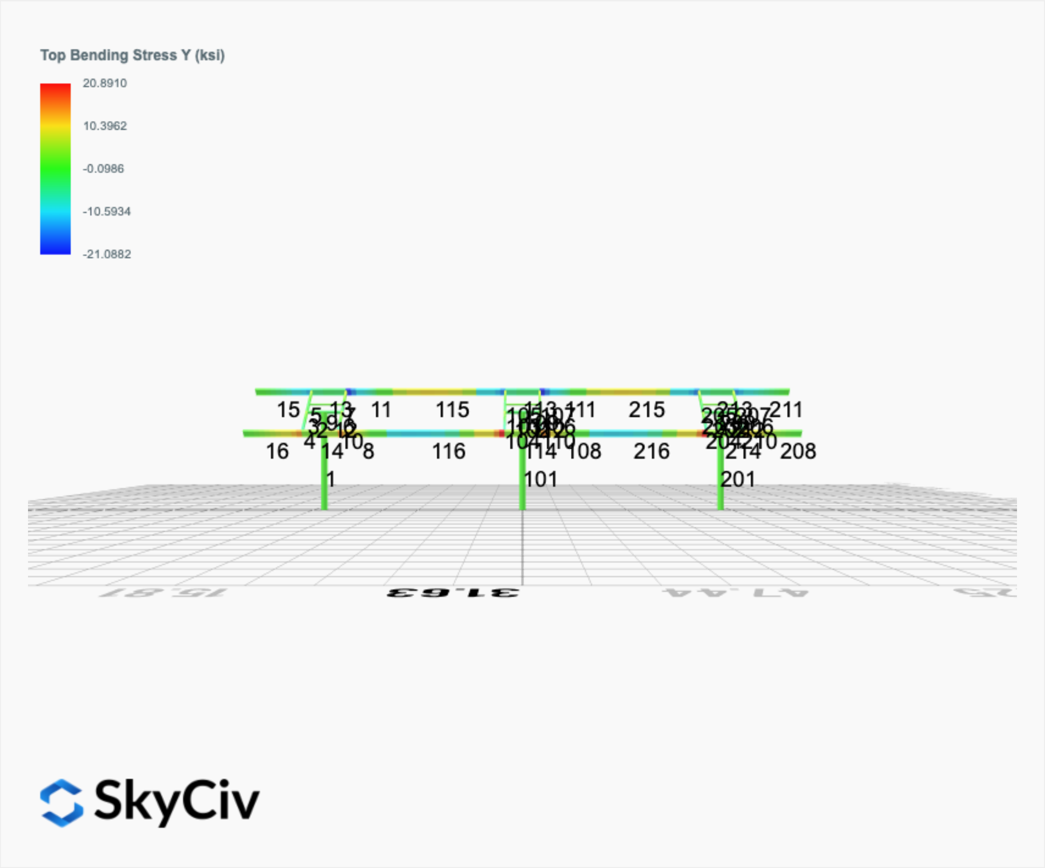
54.70
38.89
23.07
7.26
-8.55
-24.36
SkyCiv

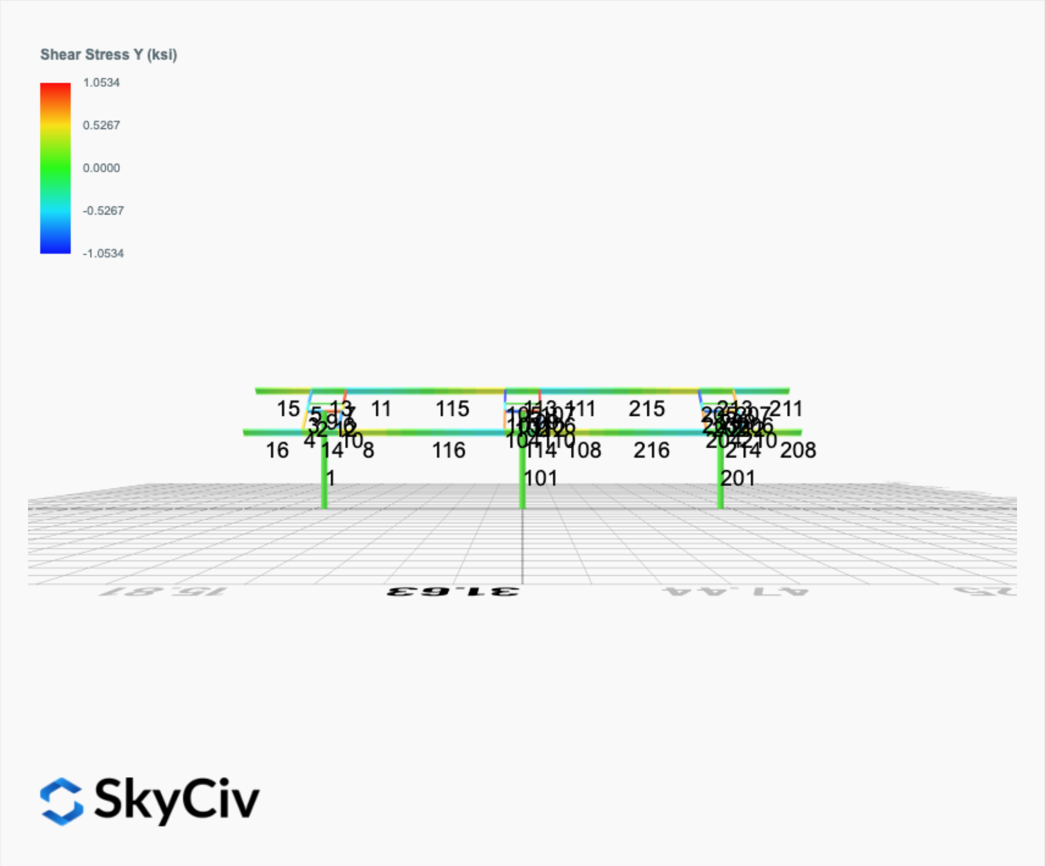

211
215
115
15
18
208
214
216
108
114
116
8
14
16
201
101
1
SkyCiv

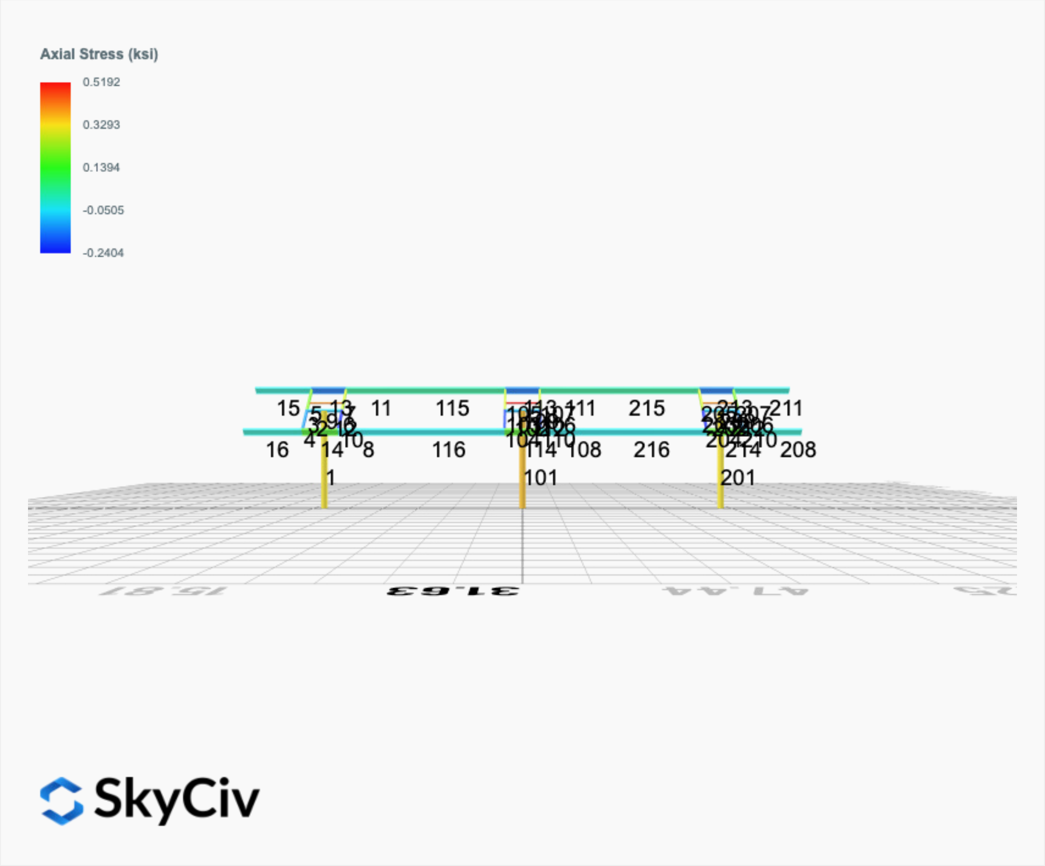
# FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
20.8910
10.3962
-0.0986
-10.5934
-21.0882
15
13
11
115
111
215
211
16
14
8
116
108
216
208
1
101
201
SkyCiv


Shear Stress Y (ksi)
1.0534
0.5267
0.0000
-0.5267
-1.0534
15
13
11
115
111
215
211
16
14
8
116
108
216
208
1
101
201
SkyCiv


Axial Stress (ksi)
0.5192
0.3293
0.1394
-0.0505
-0.2404
15
13
11
115
111
215
211
16
14
8
116
108
216
214
208
1
101
201
104
204
210
10
4
31.63
15.81
47.44
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 | 0.0123 | 2.9504 | 0.0415 | 0.1332 | -0.0080 | -0.0981 |
| ULS: 2. D + L | 0.0123 | 2.9504 | 0.0415 | 0.1332 | -0.0080 | -0.0981 |
| ULS: 3. D + (S or Lr or R) | 0.0361 | 7.1775 | 0.1218 | 0.3920 | -0.0243 | -0.3241 |
| ULS: 3. D + (S or Lr or R) | 0.0123 | 2.9504 | 0.0415 | 0.1332 | -0.0080 | -0.0981 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0301 | 6.1207 | 0.1017 | 0.3273 | -0.0202 | -0.2676 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0123 | 2.9504 | 0.0415 | 0.1332 | -0.0080 | -0.0981 |
| ULS: 5b. D + 0.7E | 0.0123 | 2.9504 | 0.0415 | 0.1332 | -0.0080 | -0.0981 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0301 | 6.1207 | 0.1017 | 0.3273 | -0.0202 | -0.2676 |
| ULS: 8. 0.6D + 0.7E | 0.0074 | 1.7702 | 0.0249 | 0.0799 | -0.0048 | -0.0589 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.3275 | 8.1007 | 0.1879 | 0.5634 | -0.5718 | 50.0307 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -4.3275 | 8.1007 | 0.1879 | 0.5634 | -0.5718 | 50.0307 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 3.4670 | -1.1507 | -0.0705 | -0.1955 | 0.4242 | -37.6886 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.9602 | -0.5438 | -0.0675 | -0.1865 | 0.4154 | -42.3207 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.2247 | 9.9834 | 0.2115 | 0.6500 | -0.4431 | 37.3290 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.2247 | 9.9834 | 0.2115 | 0.6500 | -0.4431 | 37.3290 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.6212 | 3.0449 | 0.0177 | 0.0808 | 0.3039 | -28.4605 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.2410 | 3.5001 | 0.0200 | 0.0876 | 0.2973 | -31.9346 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.2426 | 6.8131 | 0.1513 | 0.4558 | -0.4308 | 37.4985 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.2426 | 6.8131 | 0.1513 | 0.4558 | -0.4308 | 37.4985 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.6033 | -0.1254 | -0.0425 | -0.1133 | 0.3162 | -28.2910 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.2232 | 0.3298 | -0.0403 | -0.1066 | 0.3095 | -31.7651 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.3325 | 6.9205 | 0.1713 | 0.5101 | -0.5686 | 50.0700 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -4.3325 | 6.9205 | 0.1713 | 0.5101 | -0.5686 | 50.0700 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 3.4621 | -2.3309 | -0.0871 | -0.2487 | 0.4274 | -37.6494 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.9553 | -1.7240 | -0.0841 | -0.2397 | 0.4186 | -42.2815 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 14.5971 |
| Shear X | -7.2331 |
| Shear Z | 0.3362 |
| Moment X | 1.0133 |
| Moment Y (Twist) | 0.9639 |
| Moment Z | 84.3904 |

### 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 | 9.9834 |
| Shear X | -4.3325 |
| Shear Z | 0.2115 |
| Moment X | 0.6500 |
| Moment Y (Twist) | 0.5718 |
| Moment Z | 50.0700 |

## 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 | -0.0246 | 3.3066 | 0.0000 | 0.0000 | 0.0000 | 0.2817 |
| ULS: 2. D + L | -0.0246 | 3.3066 | 0.0000 | 0.0000 | 0.0000 | 0.2817 |
| ULS: 3. D + (S or Lr or R) | -0.0722 | 8.2192 | 0.0000 | -0.0000 | 0.0001 | 0.7954 |
| ULS: 3. D + (S or Lr or R) | -0.0246 | 3.3066 | 0.0000 | 0.0000 | 0.0000 | 0.2817 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0603 | 6.9910 | 0.0000 | -0.0000 | 0.0001 | 0.6669 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0246 | 3.3066 | 0.0000 | 0.0000 | 0.0000 | 0.2817 |
| ULS: 5b. D + 0.7E | -0.0246 | 3.3066 | 0.0000 | 0.0000 | 0.0000 | 0.2817 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0603 | 6.9910 | 0.0000 | -0.0000 | 0.0001 | 0.6669 |
| ULS: 8. 0.6D + 0.7E | -0.0148 | 1.9839 | 0.0000 | 0.0000 | 0.0000 | 0.1690 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.9937 | 9.2720 | 0.0000 | 0.0000 | 0.0000 | 57.2087 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -4.9937 | 9.2720 | 0.0000 | 0.0000 | 0.0000 | 57.2087 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 3.9440 | -1.4550 | 0.0000 | 0.0000 | 0.0000 | -42.3810 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 3.3157 | -0.7121 | 0.0000 | 0.0000 | 0.0000 | -47.1226 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.7871 | 11.4651 | 0.0000 | -0.0000 | 0.0001 | 43.3622 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.7871 | 11.4651 | 0.0000 | -0.0000 | 0.0001 | 43.3622 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.9162 | 3.4198 | 0.0000 | -0.0000 | 0.0001 | -31.3301 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.4449 | 3.9770 | 0.0000 | -0.0000 | 0.0001 | -34.8863 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.7514 | 7.7806 | 0.0000 | 0.0000 | 0.0000 | 42.9769 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.7514 | 7.7806 | 0.0000 | 0.0000 | 0.0000 | 42.9769 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.9518 | -0.2646 | 0.0000 | 0.0000 | 0.0000 | -31.7153 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.4806 | 0.2926 | 0.0000 | 0.0000 | 0.0000 | -35.2715 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.9839 | 7.9494 | 0.0000 | -0.0000 | 0.0000 | 57.0960 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -4.9839 | 7.9494 | 0.0000 | -0.0000 | 0.0000 | 57.0960 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 3.9538 | -2.7777 | 0.0000 | 0.0000 | 0.0000 | -42.4937 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 3.3255 | -2.0347 | 0.0000 | 0.0000 | 0.0000 | -47.2353 |

### 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 | 16.7966 |
| Shear X | -8.3308 |
| Shear Z | 0.0000 |
| Moment X | 0.0004 |
| Moment Y (Twist) | 0.0009 |
| Moment Z | 96.7664 |

### 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 | 11.4651 |
| Shear X | -4.9937 |
| Shear Z | 0.0000 |
| Moment X | -0.0000 |
| Moment Y (Twist) | 0.0001 |
| Moment Z | 57.2087 |

## 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 | 0.0123 | 2.9504 | -0.0415 | -0.1332 | 0.0080 | -0.0981 |
| ULS: 2. D + L | 0.0123 | 2.9504 | -0.0415 | -0.1332 | 0.0080 | -0.0981 |
| ULS: 3. D + (S or Lr or R) | 0.0361 | 7.1775 | -0.1218 | -0.3923 | 0.0245 | -0.3239 |
| ULS: 3. D + (S or Lr or R) | 0.0123 | 2.9504 | -0.0415 | -0.1332 | 0.0080 | -0.0981 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0301 | 6.1207 | -0.1017 | -0.3275 | 0.0204 | -0.2675 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0123 | 2.9504 | -0.0415 | -0.1332 | 0.0080 | -0.0981 |
| ULS: 5b. D + 0.7E | 0.0123 | 2.9504 | -0.0415 | -0.1332 | 0.0080 | -0.0981 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0301 | 6.1207 | -0.1017 | -0.3275 | 0.0204 | -0.2675 |
| ULS: 8. 0.6D + 0.7E | 0.0074 | 1.7702 | -0.0249 | -0.0799 | 0.0048 | -0.0589 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -4.3275 | 8.1007 | -0.1879 | -0.5634 | 0.5718 | 50.0307 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -4.3275 | 8.1007 | -0.1879 | -0.5634 | 0.5718 | 50.0307 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 3.4670 | -1.1507 | 0.0705 | 0.1954 | -0.4242 | -37.6886 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 2.9602 | -0.5438 | 0.0675 | 0.1864 | -0.4153 | -42.3207 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.2247 | 9.9834 | -0.2115 | -0.6502 | 0.4432 | 37.3292 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.2247 | 9.9834 | -0.2115 | -0.6502 | 0.4432 | 37.3292 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.6211 | 3.0449 | -0.0177 | -0.0811 | -0.3037 | -28.4603 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.2410 | 3.5001 | -0.0200 | -0.0878 | -0.2971 | -31.9344 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -3.2426 | 6.8131 | -0.1513 | -0.4558 | 0.4309 | 37.4985 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -3.2426 | 6.8131 | -0.1513 | -0.4558 | 0.4309 | 37.4985 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.6033 | -0.1254 | 0.0425 | 0.1133 | -0.3161 | -28.2910 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 2.2232 | 0.3298 | 0.0403 | 0.1065 | -0.3095 | -31.7651 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -4.3325 | 6.9205 | -0.1713 | -0.5101 | 0.5686 | 50.0700 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -4.3325 | 6.9205 | -0.1713 | -0.5101 | 0.5686 | 50.0700 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 3.4621 | -2.3309 | 0.0871 | 0.2487 | -0.4274 | -37.6493 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 2.9553 | -1.7240 | 0.0841 | 0.2397 | -0.4185 | -42.2815 |

### Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|---|---|
| Axial | 14.5970 |
| Shear X | -7.2331 |
| Shear Z | -0.3362 |
| Moment X | -1.0140 |
| Moment Y (Twist) | 0.9647 |
| Moment Z | 84.3920 |

### 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 | 9.9834 |
| Shear X | -4.3325 |
| Shear Z | -0.2115 |
| Moment X | -0.6502 |
| Moment Y (Twist) | 0.5718 |
| Moment Z | 50.0700 |

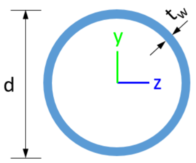
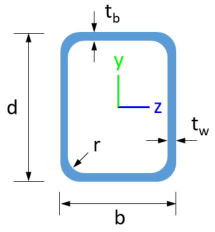
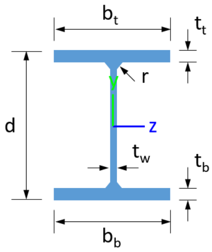
## Project Details

| | |
|---|---|
| Design Code: | AISC 360-16 LRFD |
| Provision: | LRFD |
| Country: | United States |
| User Name: | sales@mtsolar.us |
| Project Name: | John Sweeney 5x11 - V1Jb |
| 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 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <br> | | | | | | | | |
| ID | Name | d (in) | $t_w$ (in) | | | | | |
| 3 | 2in Pipe Sch 120 | 2.38 | 0.25 | | | | | |
| 6 | 4in Pipe Sch 120 | 4.50 | 0.44 | | | | | |
| 10 | 8in Pipe Sch 80 | 8.63 | 0.50 | | | | | |
| <br> | | | | | | | | |
| 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 | | |
| <br> | | | | | | | | |
| ID | Name | d (in) | $t_w$ (in) | $b_t$ (in) | $b_b$ (in) | $t_t$ (in) | $t_b$ (in) | r (in) |
| 20 | W10x12 | 9.87 | 0.19 | 3.96 | 3.96 | 0.21 | 0.21 | 0.30 |

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

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

**Member Properties**

| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 23.30 | 23.30 | 11.09 | - | 300 | 200 | 1 |
| 2 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 4 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 5 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 7 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 8 | 20 | 1.33 | 1.33 | 2.05 | 2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,1.64,2.09,2.09,2.09,1.63,2.09,2.09,2.10,2.11,2.09,2.09,2.09,2.21,2.09,2.09,2.09,1.76 | 300 | 200 | 1 |
| 9 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.81,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 11 | 20 | 1.33 | 1.33 | 2.05 | 2.10,2.10,2.10,2.10,2.10,2.10,2.11,2.11,2.12,2.13,2.11,2.11,2.11,2.12,2.11,2.11,2.09,1.71,2.11,2.11,2.12,2.13,2.11,2.11,2.11,2.12 | 300 | 200 | 1 |
| 12 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.09,1.06,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.09 | 300 | 200 | 1 |
| 14 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,2.86,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.86,1.08,1.08,1.08,1.05 | 300 | 200 | 1 |
| 15 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 101 | 10 | 23.30 | 23.30 | 11.09 | - | 300 | 200 | 1 |
| 102 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 104 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.76,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 105 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 106 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 107 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 108 | 20 | 1.33 | 1.33 | 2.05 | 2.29,2.29,2.29,2.29,2.29,2.29,2.31,2.31,2.35,2.08,2.31,2.31,2.33,2.23,2.30,2.30,2.24,2.29,2.31,2.31,2.35,2.14,2.32,2.32,2.33,2.24 | 300 | 200 | 1 |
| 109 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.76,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 111 | 20 | 1.33 | 1.33 | 2.05 | 2.32,2.32,2.32,2.33,2.32,2.32,2.11,2.11,1.86,1.91,2.10,2.10,2.08,2.07,2.14,2.14,1.88,1.37,2.11,2.11,1.79,1.87,2.10,2.10,2.08,2.08 | 300 | 200 | 1 |
| 112 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 113 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.03,1.03,1.03,1.04,1.03,1.03,1.02,1.01,1.03,1.03,1.04,1.04,1.03,1.03,1.03,1.03 | 300 | 200 | 1 |
| 114 | 20 | 4.88 | 4.00 | 7.50 | 1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.44,1.03,1.03,1.03,1.02,1.03,1.03,1.02,1.03,1.03,1.03,1.03,2.12,1.03,1.03,1.03,1.02 | 300 | 200 | 1 |
| 115 | 20 | 8.42 | 8.42 | 12.95 | 1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.14,1.12,1.12,1.14,1.14,1.13,1.13,1.15,1.15,1.22,1.95,1.14,1.14,1.12,1.12,1.14,1.14,1.13,1.13 | 300 | 200 | 1 |
| 116 | 20 | 8.42 | 8.42 | 12.95 | 1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.19,1.17,1.17,1.18,1.17,1.17,1.17,1.16,1.15,1.17,1.17,1.16,1.19 | 300 | 200 | 1 |
| 201 | 10 | 23.30 | 23.30 | 11.09 | - | 300 | 200 | 1 |
| 202 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 204 | 17 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.81,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.76,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 205 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67 | 300 | 200 | 1 |
| 206 | 17 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 207 | 17 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 208 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 209 | 3 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 17 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.63,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65 | 300 | 200 | 1 |
| 211 | 20 | 9.97 | 9.97 | 4.75 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 212 | 6 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.09,1.07,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.09 | 300 | 200 | 1 |
| 214 | 20 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,2.89,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.86,1.08,1.08,1.08,1.05 | 300 | 200 | 1 |
| 215 | 20 | 8.42 | 8.42 | 12.95 | 1.13,1.13,1.13,1.13,1.13,1.13,1.14,1.14,1.15,1.15,1.14,1.14,1.14,1.15,1.14,1.14,1.15,1.19,1.14,1.14,1.15,1.15,1.14,1.14,1.14,1.15 | 300 | 200 | 1 |
| 216 | 20 | 8.42 | 8.42 | 12.95 | 1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.27,1.13,1.13,1.13,1.12,1.13,1.13,1.14,1.14,1.13,1.13,1.13,1.19,1.13,1.13,1.13,1.13 | 300 | 200 | 1 |

## Member Design Capacity

| **Member ID** | **$\Phi_tP_n$ (kip)** | **$\Phi_cP_n$ (kip)** | **$\Phi_bM_{zn}$ (k-ft)** | **$\Phi_bM_{yn}$ (k-ft)** | **$\Phi_vV_{yn}$ (kip)** | **$\Phi_vV_{zn}$ (kip)** |
|---|---|---|---|---|---|---|
| 1 | 574.32 | 288.12 | 123.94 | 123.94 | 172.30 | 172.30 |
| 2 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 3 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 4 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 5 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 6 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 7 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 8 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 9 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 10 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 11 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 12 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 13 | 159.30 | 97.43 | 32.55 | 6.46 | 56.26 | 44.91 |
| 14 | 159.30 | 97.43 | 32.14 | 6.46 | 56.26 | 44.91 |
| 15 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 16 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 101 | 574.32 | 288.12 | 123.94 | 123.94 | 172.30 | 172.30 |
| 102 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 103 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 104 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 105 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 106 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 107 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 108 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 109 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 110 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 111 | 159.30 | 140.46 | 46.90 | 6.46 | 56.26 | 44.91 |
| 112 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 113 | 159.30 | 97.43 | 30.96 | 6.46 | 56.26 | 44.91 |
| 114 | 159.30 | 97.43 | 31.08 | 6.46 | 56.26 | 44.91 |
| 115 | 159.30 | 48.27 | 14.84 | 6.46 | 56.26 | 44.91 |
| 116 | 159.30 | 48.27 | 15.26 | 6.46 | 56.26 | 44.91 |
| 201 | 574.32 | 288.12 | 123.94 | 123.94 | 172.30 | 172.30 |
| 202 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 203 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 204 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 205 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 206 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 207 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 208 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 209 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 210 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 211 | 159.30 | 34.37 | 46.90 | 6.46 | 56.26 | 44.91 |
| 212 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 213 | 159.30 | 97.43 | 32.57 | 6.46 | 56.26 | 44.91 |
| 214 | 159.30 | 97.43 | 32.12 | 6.46 | 56.26 | 44.91 |
| 215 | 159.30 | 48.27 | 15.07 | 6.46 | 56.26 | 44.91 |
| 216 | 159.30 | 48.27 | 14.93 | 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 | 0.051 | 0.681 | 0.022 | 0.042 | 0.002 | 0.714 | #13 | 0.486 | Not Required | Pass |
| 2 | 0.006 | 0.370 | 0.242 | 0.084 | 0.046 | 0.613 | #13 | 0.036 | Not Required | Pass |
| 3 | 0.009 | 0.672 | 0.052 | 0.066 | 0.008 | 0.687 | #13 | 0.046 | Not Required | Pass |
| 4 | 0.009 | 0.631 | 0.190 | 0.063 | 0.041 | 0.708 | #13 | 0.082 | Not Required | Pass |
| 5 | 0.009 | 0.417 | 0.187 | 0.066 | 0.049 | 0.439 | #13 | 0.076 | Not Required | Pass |
| 6 | 0.012 | 0.775 | 0.077 | 0.078 | 0.009 | 0.822 | #13 | 0.046 | Not Required | Pass |
| 7 | 0.012 | 0.481 | 0.252 | 0.077 | 0.065 | 0.516 | #13 | 0.076 | Not Required | Pass |
| 8 | 0.002 | 0.065 | 0.311 | 0.047 | 0.026 | 0.329 | #21 | 0.102 | Not Required | Pass |
| 9 | 0.025 | 0.063 | 0.077 | 0.002 | 0.003 | 0.141 | #13 | 0.206 | Not Required | Pass |
| 10 | 0.012 | 0.713 | 0.240 | 0.071 | 0.051 | 0.771 | #13 | 0.082 | Not Required | Pass |
| 11 | 0.003 | 0.065 | 0.319 | 0.052 | 0.026 | 0.346 | #21 | 0.102 | Not Required | Pass |
| 12 | 0.005 | 0.469 | 0.278 | 0.102 | 0.051 | 0.748 | #13 | 0.036 | Not Required | Pass |
| 13 | 0.009 | 0.279 | 0.671 | 0.064 | 0.032 | 0.857 | #21 | 0.306 | Not Required | Pass |
| 14 | 0.012 | 0.261 | 0.660 | 0.059 | 0.032 | 0.828 | #21 | 0.204 | Not Required | Pass |
| 15 | 0.000 | 0.094 | 0.269 | 0.033 | 0.016 | 0.349 | #21 | Not Required | Not Required | Pass |

|  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 0.000 | 0.094 | 0.269 | 0.033 | 0.016 | 0.349 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.088 | 0.269 | 0.031 | 0.016 | 0.346 | #21 | Not Required | Not Required | Pass |
| 101 | 0.058 | 0.781 | 0.000 | 0.048 | 0.000 | 0.809 | #13 | 0.486 | Not Required | Pass |
| 102 | 0.006 | 0.484 | 0.300 | 0.108 | 0.055 | 0.785 | #13 | 0.036 | Not Required | Pass |
| 103 | 0.012 | 0.823 | 0.059 | 0.082 | 0.002 | 0.856 | #13 | 0.046 | Not Required | Pass |
| 104 | 0.012 | 0.792 | 0.243 | 0.079 | 0.051 | 0.874 | #13 | 0.082 | Not Required | Pass |
| 105 | 0.012 | 0.511 | 0.254 | 0.081 | 0.067 | 0.547 | #13 | 0.076 | Not Required | Pass |
| 106 | 0.012 | 0.823 | 0.059 | 0.082 | 0.002 | 0.856 | #13 | 0.046 | Not Required | Pass |
| 107 | 0.012 | 0.511 | 0.255 | 0.081 | 0.067 | 0.547 | #13 | 0.076 | Not Required | Pass |
| 108 | 0.002 | 0.065 | 0.317 | 0.051 | 0.026 | 0.376 | #21 | 0.102 | Not Required | Pass |
| 109 | 0.029 | 0.061 | 0.060 | 0.001 | 0.000 | 0.128 | #13 | 0.206 | Not Required | Pass |
| 110 | 0.012 | 0.792 | 0.243 | 0.079 | 0.051 | 0.874 | #13 | 0.082 | Not Required | Pass |
| 111 | 0.003 | 0.066 | 0.324 | 0.052 | 0.026 | 0.371 | #21 | 0.102 | Not Required | Pass |
| 112 | 0.006 | 0.484 | 0.300 | 0.108 | 0.055 | 0.785 | #13 | 0.036 | Not Required | Pass |
| 113 | 0.009 | 0.273 | 0.677 | 0.064 | 0.032 | 0.903 | #21 | 0.306 | Not Required | Pass |
| 114 | 0.014 | 0.303 | 0.669 | 0.062 | 0.032 | 0.911 | #21 | 0.306 | Not Required | Pass |
| 115 | 0.010 | 0.580 | 0.359 | 0.052 | 0.026 | 0.847 | #21 | 0.644 | Not Required | Pass |
| 116 | 0.004 | 0.515 | 0.358 | 0.051 | 0.026 | 0.804 | #21 | 0.644 | Not Required | Pass |
| 201 | 0.051 | 0.681 | 0.022 | 0.042 | 0.002 | 0.714 | #13 | 0.486 | Not Required | Pass |
| 202 | 0.005 | 0.469 | 0.278 | 0.102 | 0.051 | 0.748 | #13 | 0.036 | Not Required | Pass |
| 203 | 0.012 | 0.775 | 0.077 | 0.078 | 0.009 | 0.822 | #13 | 0.046 | Not Required | Pass |
| 204 | 0.012 | 0.713 | 0.240 | 0.071 | 0.051 | 0.771 | #13 | 0.082 | Not Required | Pass |
| 205 | 0.012 | 0.481 | 0.252 | 0.077 | 0.065 | 0.516 | #13 | 0.076 | Not Required | Pass |
| 206 | 0.009 | 0.672 | 0.052 | 0.066 | 0.008 | 0.687 | #13 | 0.046 | Not Required | Pass |
| 207 | 0.009 | 0.417 | 0.187 | 0.066 | 0.049 | 0.439 | #13 | 0.076 | Not Required | Pass |
| 208 | 0.000 | 0.088 | 0.269 | 0.031 | 0.016 | 0.346 | #21 | Not Required | Not Required | Pass |
| 209 | 0.025 | 0.063 | 0.077 | 0.002 | 0.003 | 0.141 | #13 | 0.206 | Not Required | Pass |
| 210 | 0.009 | 0.631 | 0.190 | 0.063 | 0.041 | 0.708 | #13 | 0.082 | Not Required | Pass |
| 211 | 0.000 | 0.094 | 0.269 | 0.033 | 0.016 | 0.349 | #21 | Not Required | Not Required | Pass |
| 212 | 0.006 | 0.370 | 0.242 | 0.084 | 0.046 | 0.613 | #13 | 0.036 | Not Required | Pass |
| 213 | 0.009 | 0.279 | 0.671 | 0.064 | 0.032 | 0.857 | #21 | 0.204 | Not Required | Pass |
| 214 | 0.012 | 0.261 | 0.661 | 0.059 | 0.032 | 0.828 | #21 | 0.306 | Not Required | Pass |
| 215 | 0.010 | 0.580 | 0.360 | 0.052 | 0.026 | 0.848 | #21 | 0.644 | Not Required | Pass |
| 216 | 0.004 | 0.525 | 0.356 | 0.047 | 0.026 | 0.810 | #21 | 0.644 | Not Required | Pass |

## Definitions

|  |  |
|---|---|
| $\Phi_t$ | Safety factor for tensile |
| $\Phi_c$ | Safety factor for compression |
| $\Phi_b$ | Safety factor for flexure |
| $\Phi_v$ | Safety factor for shear |
| E | Modulus of elasticity |
| $F_y$ | Specified minimum yield stress |
| $F_u$ | Specified minimum tensile strength |
| A | Cross-sectional area |
| J | Torsional constant |
| $I_{yp}$ | Moment of inertia about the Y axes |
| $I_{zp}$ | Moment of inertia about the Z axes |
| $I_w$ | Warping constant |
| $S_{yp}$ | Plastic section modulus about the Y axis |
| $S_{zp}$ | Plastic section modulus about the Z axis |
| KL | Effective length |
| $C_b$ | Buckling modification factor (from all load combinations) |
| $L_b$ | Length between braced points |
| LST | Limited slenderness for tension |
| LSC | Limited slenderness for compression |
| LD | Limited deflection |

| | |
|---|---|
| $P_n$ | Nominal axial strength (tension/comression) |
| $M_n$ | Nominal flexural strength (about Z/Y axis) |
| $V_n$ | Nominal shear strength (along Z/Y axis) |
| P | Design ratio in case of axial force |
| $M_z$ | Design ratio in case of bending about Z axis |
| $M_y$ | Design ratio in case of bending about Y axis |
| $V_y$ | Design ratio in case of shear along Y axis |
| $V_z$ | Design ratio in case of shear along Z axis |
| $(P,M_z,M_y)$ | Design ratio in case of axial force and bending action |
| KL/r | Design ratio in case of section slenderness |
| δ | Design ratio in case of member deflection |
| OK | Capacity is provided |
| NG | Capacity is not provided |

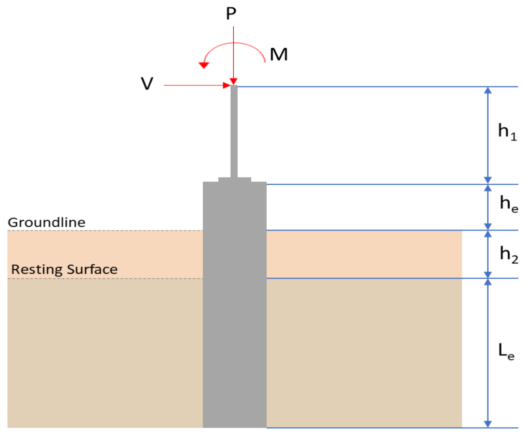
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input



**Geometry**

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7.75\ \text{ft}$ - 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) | 9.983 | 14.597 |
| $V_x$ (kip) | -4.332 | -7.233 |
| $V_z$ (kip) | 0.212 | 0.336 |
| $M_x$ (kipft) | 0.650 | 1.013 |
| $M_z$ (kipft) | 50.070 | 84.390 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.332\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.68981\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(50.07 \text{ kipft}) + ((-4.332 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.9729 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.0271 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.212 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.033758 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.65 \text{ kipft}) + ((0.212 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.1035 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.3543 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.0271 \text{ ft}), (2.3543 \text{ ft})]$$

$$L_{e,req} = 7.027 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.027 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.90671$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\, D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(9.983\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.62394\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.62394\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.31197$$

Status: **PASS**
Ratio: **0.310**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.68981\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.9729\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9729\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (7.9729\ \mathrm{kipft/ft})) + (4 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.3662\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.9729\ \mathrm{kipft/ft})) + (3 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (7.9729\ \mathrm{kipft/ft})) + (2 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.23728\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (7.9729\ \mathrm{kipft/ft})) + ((-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 1.0589\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3662\ \mathrm{ft})}{2}$$

$$p_a = 0.40246\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23728\ \mathrm{kip/ft^2}\right)}{\left(0.40246\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.58957$$

Status: **PASS**
Ratio: **0.590**

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0589\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91087$$

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

**Considering z-direction:**

$H_o = 0.033758\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.1035\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1035\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.1035\ \mathrm{kipft/ft})) + (4 \times (0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.572\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.1035\ \mathrm{kipft/ft})) + (3 \times (0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^2}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.1035\ \mathrm{kipft/ft})) + (2 \times (0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.021526\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.1035\ \mathrm{kipft/ft})) + ((0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 0.046814\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.572\ \mathrm{ft})}{2}$$

$$p_a = 0.4179\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.021526\ \mathrm{kip/ft^2}\right)}{\left(0.4179\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.051511$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

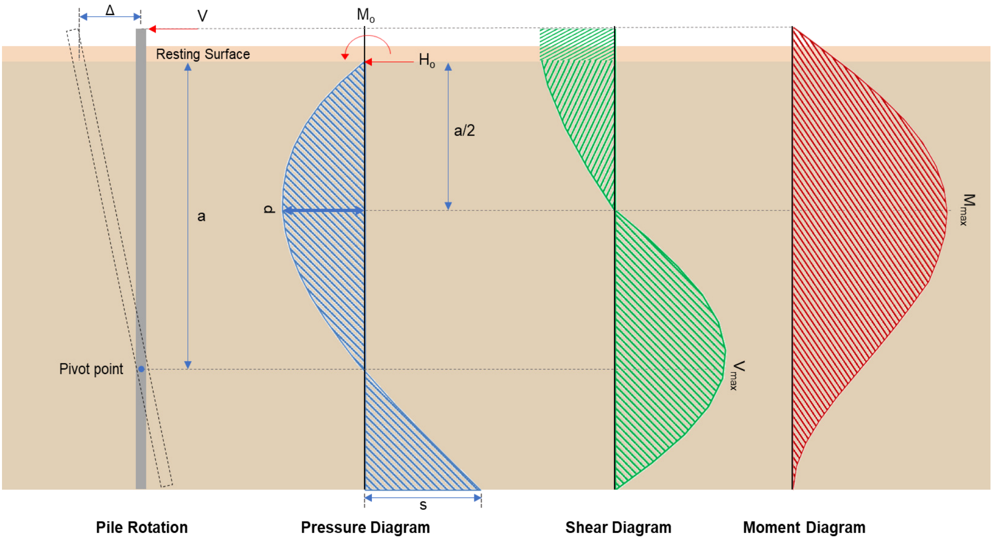
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.046814\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.04027$$

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



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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-7.233\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1518\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(84.39\ \mathrm{kipft}) + ((-7.233\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.438\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(13.438\ \mathrm{kipft/ft})}{(-1.1518\ \mathrm{kip/ft})}$$

$$E = 11.667\ \mathrm{ft}$$

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

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

$$(4 \times (13.438\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-1.1518\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (13.438\ \mathrm{kipft/ft})) + (4 \times (-1.1518\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.3649\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.1518\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.667\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3649\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.667\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3649\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.31\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.1518\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.75\ \mathrm{ft})) \times \left[\left(\frac{(11.667\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + \frac{(5.3649\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.667\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.3649\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.667\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.3649\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 56.092\ \mathrm{kipft}$$

---

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.336\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.053503\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.013\ \mathrm{kipft}) + ((0.336\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.16131\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.16131\ \mathrm{kipft/ft})}{(0.053503\ \mathrm{kip/ft})}$$

$$E = 3.0149\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.16131\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.053503\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.16131\ \mathrm{kipft/ft})) + (4 \times (0.053503\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.5745\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.053503\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0149\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5745\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0149\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5745\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.29046\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.053503\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.75\ \mathrm{ft})) \times \left[\left(\frac{(3.0149\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + \frac{(5.5745\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.0149\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5745\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0149\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5745\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.97809\ \mathrm{kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

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

$$A_{st,required} = Min\left[\frac{\frac{(14.597\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.111\ \mathrm{in}^2$$

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

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

$$A_{min} = Max\left[(-84.111\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

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

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.597\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0054565$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 14.597 \text{ kip} \rightarrow 14597 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14597 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.43 \text{ kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.43 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.43 \text{ kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

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

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

$$\phi V_n = (0.65) \times ((120.43 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.36 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 15.31 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.31\ \text{kip})}{(111.36\ \text{kip})}$$

$$Ratio = 0.13748$$

Status: **PASS**
Ratio: **0.140**

**Considering z-direction:**

$V_{max} = 0.29046\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.29046\ \text{kip})}{(111.36\ \text{kip})}$$

$$Ratio = 0.0026083$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$

$$\phi M_n = 249.6\ \text{kipft}$$

**Considering x-direction:**

$M_{max} = 56.092\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(56.092\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.22473$$

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

**Considering z-direction:**

$M_{max} = 0.97809\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $Ratio = \frac{(0.97809 \text{ kipft})}{(249.6 \text{ kipft})}$<br>$Ratio = 0.0039186$ | Status: **PASS**<br>Ratio: **0.000** |

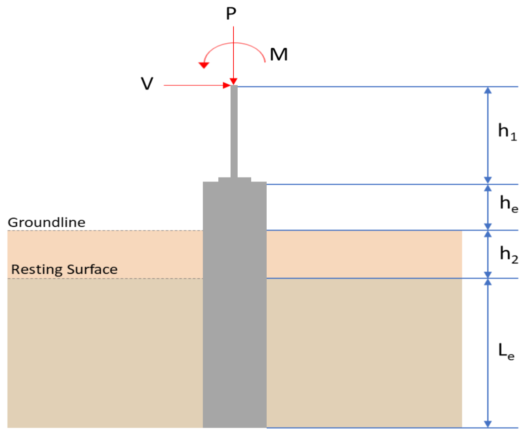
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input



**Geometry**

Pile shape: rectangular

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

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

$L = 7.75\ \text{ft}$ - 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) | 9.983 | 14.597 |
| $V_x$ (kip) | -4.332 | -7.233 |
| $V_z$ (kip) | -0.212 | -0.336 |
| $M_x$ (kipft) | -0.650 | -1.014 |
| $M_z$ (kipft) | 50.070 | 84.392 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.332\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.68981\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(50.07\ \text{kipft}) + ((-4.332\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.9729\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.0271\ \text{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.212\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.033758\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.65\ \text{kipft}) + ((-0.212\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.1035\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.6928\ \text{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.0271\ \text{ft}), (1.6928\ \text{ft})]$$

$$L_{e,req} = 7.027\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.027\ \text{ft})}{(7.75\ \text{ft})}$$

$$Ratio = 0.90671$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cross-section area

$$A = b\ D$$

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

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

$q$ - End-bearing pressure

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

$$q = \frac{(9.983\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.62394\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.62394\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.31197$$

Status: **PASS**
Ratio: **0.310**

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*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.68981\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.9729\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9729\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (7.9729\ \mathrm{kipft/ft})) + (4 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.3662\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.9729\ \mathrm{kipft/ft})) + (3 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (7.9729\ \mathrm{kipft/ft})) + (2 \times (-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.23728\ \mathrm{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (7.9729\ \mathrm{kipft/ft})) + ((-0.68981\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 1.0589\ \mathrm{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3662\ \mathrm{ft})}{2}$$

$$p_a = 0.40246\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23728\ \mathrm{kip/ft^2}\right)}{\left(0.40246\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.58957$$

Status: **PASS**
Ratio: **0.590**

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

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0589\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91087$$

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

**Considering z-direction:**

$H_o = -0.033758\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.1035\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1035\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.1035\ \mathrm{kipft/ft})) + (4 \times (-0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.572\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.1035\ \mathrm{kipft/ft})) + (3 \times (-0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^2}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.1035\ \mathrm{kipft/ft})) + (2 \times (-0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = -0.0080729\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{6 \times [(2 \times (0.1035\ \mathrm{kipft/ft})) + ((-0.033758\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = -0.0054561\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.572\ \mathrm{ft})}{2}$$

$$p_a = 0.4179\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0080729\ \mathrm{kip/ft^2}\right)}{\left(0.4179\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.019318$$

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

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

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

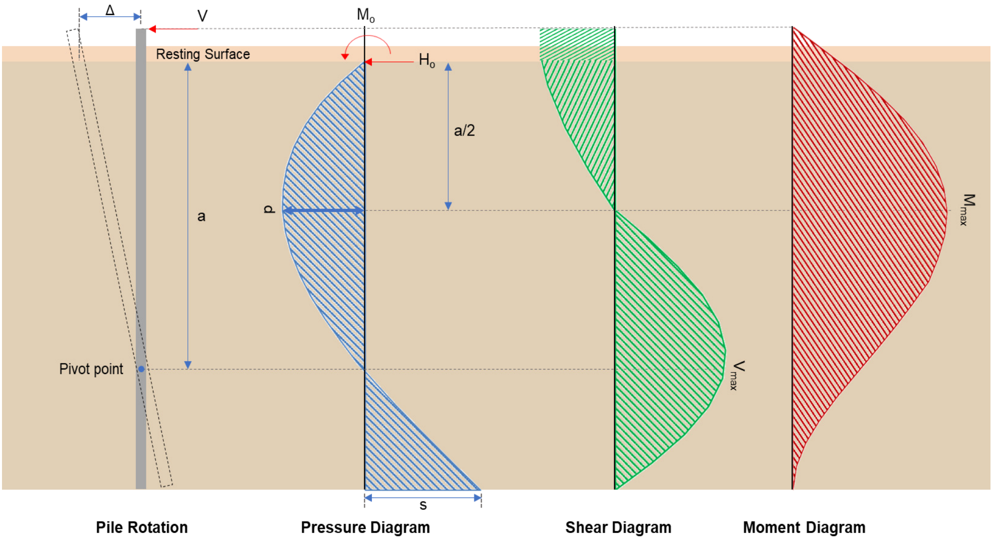
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0054561\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0046934$$

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



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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-7.233\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1518\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(84.392\ \mathrm{kipft}) + ((-7.233\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.438\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(13.438\ \mathrm{kipft/ft})}{(-1.1518\ \mathrm{kip/ft})}$$

$$E = 11.668\ \mathrm{ft}$$

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

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

$$(4 \times (13.438\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-1.1518\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (13.438\ \text{kipft/ft})) + (4 \times (-1.1518\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3649\ \text{ft}$$

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

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

$$V_{max} = ((-1.1518\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.668\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3649\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.668\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3649\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.311\ \text{kip}$$

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

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

$$M_{max} = ((-1.1518\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(11.668\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.3649\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.668\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3649\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.668\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3649\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 56.093\ \text{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.336\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.053503\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(1.014\ \text{kipft}) + ((-0.336\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.16146\ \text{kipft/ft}$$

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

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

$$E = \frac{(0.16146\ \text{kipft/ft})}{(-0.053503\ \text{kip/ft})}$$

$$E = 3.0179\ \text{ft}$$

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

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

$$a = \frac{(4 \times (0.16146\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.053503\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.16146\ \text{kipft/ft})) + (4 \times (-0.053503\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5744\ \text{ft}$$

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

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

$$V_{max} = ((-0.053503\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0179\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5744\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0179\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5744\ \mathrm{ft})}{(7.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.29061\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.053503\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.75\ \mathrm{ft})) \times \left[\left(\frac{(3.0179\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + \frac{(5.5744\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.0179\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.5744\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0179\ \mathrm{ft})}{(7.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.5744\ \mathrm{ft})}{2 \times (7.75\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.97864\ \mathrm{kipft}$$

---

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

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

$$A_{st,required} = Min\left[\frac{\frac{(14.597\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.111\ \mathrm{in}^2$$

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

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

$$A_{min} = Max\left[(-84.111\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

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

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

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

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

**Ties:**

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

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

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

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

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

**Summary:**

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

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.597 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0054565$$

Status: PASS
Ratio: 0.010

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 14.597 \text{ kip} \rightarrow 14597 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14597 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.43 \text{ kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.43 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.43 \text{ kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

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

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

$$\phi V_n = (0.65) \times ((120.43 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.36 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 15.311 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.311\ \mathrm{kip})}{(111.36\ \mathrm{kip})}$$

$$Ratio = 0.13749$$

Status: **PASS**
Ratio: **0.140**

**Considering z-direction:**

$V_{max} = 0.29061\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.29061\ \mathrm{kip})}{(111.36\ \mathrm{kip})}$$

$$Ratio = 0.0026096$$

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

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$

$$\phi M_n = 249.6\ \mathrm{kipft}$$

**Considering x-direction:**

$M_{max} = 56.093\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(56.093\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.22473$$

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

**Considering z-direction:**

$M_{max} = 0.97864\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

| | | |
|---|---|---|
| | $Ratio = \frac{(0.97864 \text{ kipft})}{(249.6 \text{ kipft})}$<br>$Ratio = 0.0039208$ | Status: **PASS**<br>Ratio: **0.000** |

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

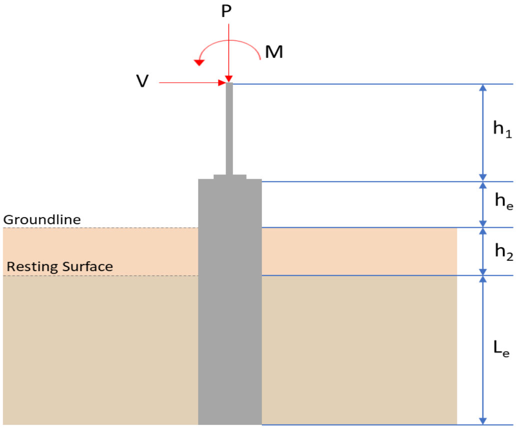
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input



**Geometry**

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 8\ \mathrm{ft}$ - 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) | 11.465 | 16.797 |
| $V_x$ (kip) | -4.994 | -8.331 |
| $V_z$ (kip) | 0.000 | 0.000 |
| $M_x$ (kipft) | 0.000 | 0.000 |
| $M_z$ (kipft) | 57.209 | 96.766 |

**Material Properties**

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

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

$H$ - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

**Considering x-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-4.994\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.79522\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(57.209\ \text{kipft}) + ((-4.994\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 9.1097\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.2586\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(7.2586\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 7.259\ \text{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.259\ \text{ft})}{(8\ \text{ft})}$$

$$Ratio = 0.90738$$

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

### 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

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

$$q = \frac{(11.465\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.71656\ \text{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.71656\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.35828$$

Status: **PASS**
Ratio: **0.360**

*Czerniak*

### Lateral Soil Pressure (ASD):

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

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

$$L/D = \frac{(8\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.79522\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.1097\ \text{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.1097\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (-0.79522\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (9.1097\ \text{kipft/ft})) + (4 \times (-0.79522\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5451\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (9.1097\ \text{kipft/ft})) + (3 \times (-0.79522\ \text{kip/ft}) \times (8\ \text{ft}))]^2}{(8\ \text{ft})^2 \times [(3 \times (9.1097\ \text{kipft/ft})) + (2 \times (-0.79522\ \text{kip/ft}) \times (8\ \text{ft}))]}$$

$$p = 0.24162\ \text{kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (9.1097\ \text{kipft/ft})) + ((-0.79522\ \text{kip/ft}) \times (8\ \text{ft}))]}{(8\ \text{ft})^2}$$

$$s = 1.1117\ \text{kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.5451\ \text{ft})}{2}$$

$$p_a = 0.41588\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24162\ \text{kip/ft}^2\right)}{\left(0.41588\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.58099$$

Status: **PASS**
Ratio: **0.580**

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

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (8\ \text{ft})$$

$$p_s = 1.2\ \text{kip/ft}^2$$

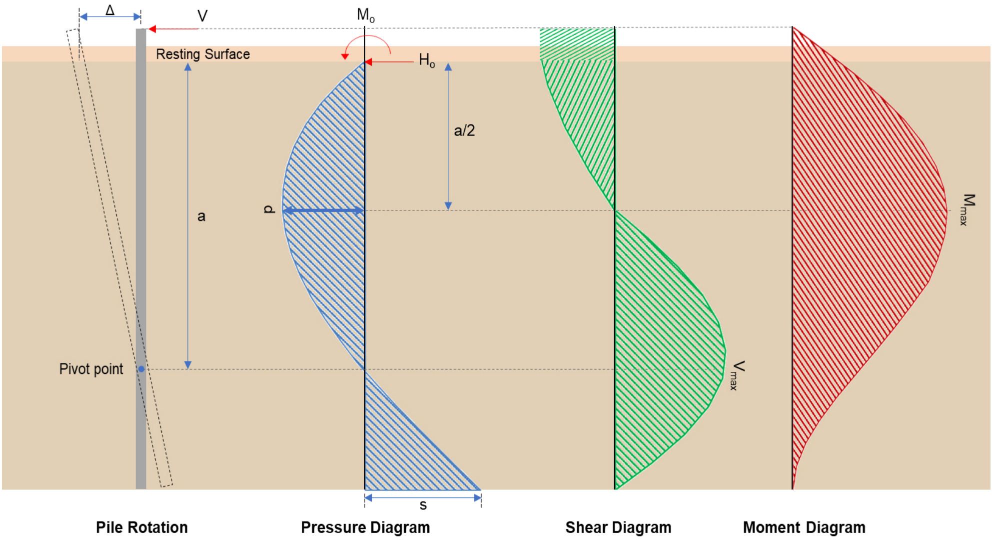
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1117\ \text{kip/ft}^2\right)}{\left(1.2\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.92638$$

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



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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-8.331\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.3266\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(96.766\ \text{kipft}) + ((-8.331\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 15.409\ \text{kipft/ft}$$

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

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

$$E = \frac{(15.409\ \text{kipft/ft})}{(-1.3266\ \text{kip/ft})}$$

$$E = 11.615\ \text{ft}$$

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

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

$$a = \frac{(4 \times (15.409\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (-1.3266\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (15.409\ \text{kipft/ft})) + (4 \times (-1.3266\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5431\ \text{ft}$$

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

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

$$V_{max} = ((-1.3266\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.615\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5431\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.615\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5431\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V \quad 17.132\ \text{kip}$$

$$V_{max} = 17.132\ \text{kip}$$

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

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

$$M_{max} = ((-1.3266\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(11.615\ \text{ft})}{(8\ \text{ft})} + \frac{(5.5431\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.615\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5431\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.615\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5431\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 64.681\ \text{kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

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

**Longitudinal reinforcement:**

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

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

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

$$A_{st,required} = Min\left[\frac{\frac{(16.797\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.038\ \text{in}^2$$

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

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

$$A_{min} = Max\left[(-84.038\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

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

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

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

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

**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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.797 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0062788$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 16.797 \text{ kip} \rightarrow 16797 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(16797\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.72\ \text{kip}$$

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

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

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.72\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.72\ \text{kip}$$

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

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

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

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

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

$A_v$ - Ties rebar area,

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

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

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

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

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

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

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

$V_s$ - Governing shear strength of steel

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

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

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

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

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

$$\phi V_n = (0.65) \times ((120.72\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.55\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 17.132\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.132\ \text{kip})}{(111.55\ \text{kip})}$$

$$Ratio = 0.15357$$

Status: **PASS**
Ratio: **0.150**

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

$S_m$ - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$

$$\phi M_n = 249.6\text{ kipft}$$

**Considering x-direction:**

$M_{max} = 64.681\text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(64.681\text{ kipft})}{(249.6\text{ kipft})}$$

$$Ratio = 0.25914$$

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