# Your Project Calculations

Project Name: NMSUAgro-JB-RevB1

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=NMSUAgro-JB-RevB1&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=LqE18ijWGKPx3NnjVHPoxlC6Qahcbm0HG38CmxHhGDZLJbOxNeZuqTXGzODiDOk7

## Array Specification

| | |
|---|---|
| **Product:** | Beam |
| **Unique ID:** | 3P-19.75-6TOP-HD-72-L-4Hx9W-JEF4 |
| **Duty Classification:** | HD |
| **Module Width:** | 40.00 in |
| **Module Length:** | 78.00in |
| **Number of Rows:** | 4 |
| **Number of Columns:** | 9 |
| **Total Number of Modules:** | 36 |
| **Desired Tilt Angle:** | 15 |
| **Front Edge Clearance:** | 8 |
| **Total Array Height at Tilt:** | 11.47 ft |
| **Total Frame Length:** | 59.00 ft |
| **Frame Weight:** | 2379 lbs |
| **Array Dimensions N/S:** | 13.50 ft |
| **Array Dimensions E/W:** | 59.25 ft |
| **Rail Length:** | 162.00 in |
| **Rail Spacing:** | 3.29 ft |
| **Rail Check:** | PASS (28% utilized) |

## Support Specifications

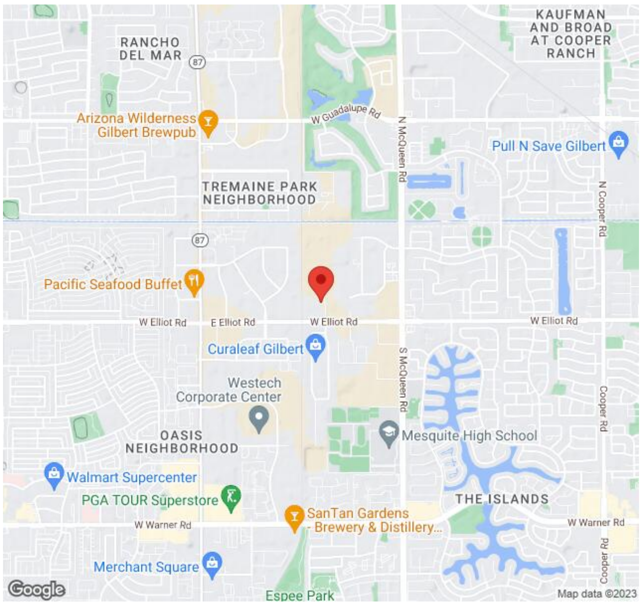
| | |
|---|---|
| **Pole Size:** | 6in Pipe Sch 40 |
| **Pole Length above Grade:** | 9.75 ft |
| **Number of Poles:** | 3 |
| **Pole Spacing:** | 19.75 ft |

## Foundation Specifications

| | |
|---|---|
| **Foundation Type:** | Round |
| **Foundation Dimensions:** | Ø48 in |
| **Foundation Depth (below grade):** | Pile 1: 6.75 ft<br>Pile 2: 6.75 ft<br>Pile 3: 6.75 ft |
| **Foundation Volume:** | 9.425 $y^3$ |
| **Foundation Result:** | PASSED |
| **Mount Twist:** | 0.188336 kip |

## Site Info

| | |
|---|---|
| **Risk Category:** | I |
| **Exposure:** | C |
| **Soil Classification:** | sandy_gravel |
| **Site Location:** | 150 N William Dillard Dr, Gilbert, AZ 85233, USA |
| **Wind Speed:** | 105 mph |
| **Snow Load:** | 15 psf |
| **Design Uplift Pressure:** | Multiple pressures |
| **Design Downforce Pressure:** | Multiple pressures |
| **Design Snow Pressure:** | 0.009072 ksf |




### Design Disclaimer

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

### AutoDesigner Input


```
{"wind_speed_override":105,"snow_load_override":15,"direct_snow_load":false,"product_type":"Beam","project_id":"NMSUAgro-JB-RevB1","site_address":"150 N William Dillard Dr, Gilbert, AZ 85233, USA","module_width":40,"module_length":78,"number_rows":"4","number_columns":9,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":15,"ground_clearance":8,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sandy_gravel","customer_foundation_override":"48_Square","foundation_type":"Round","foundation_size":48,"check_rails":true}
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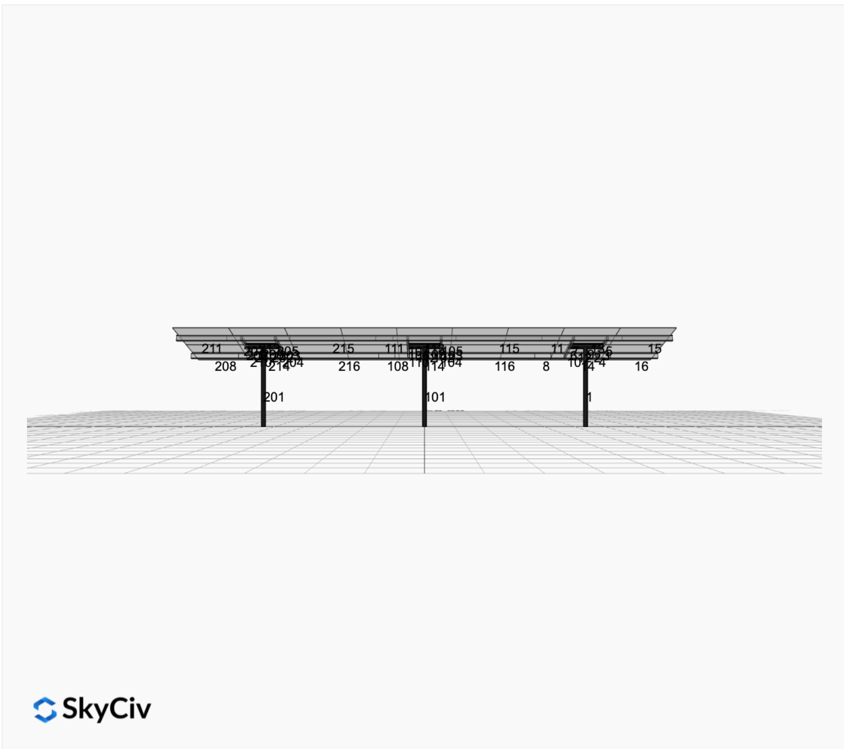
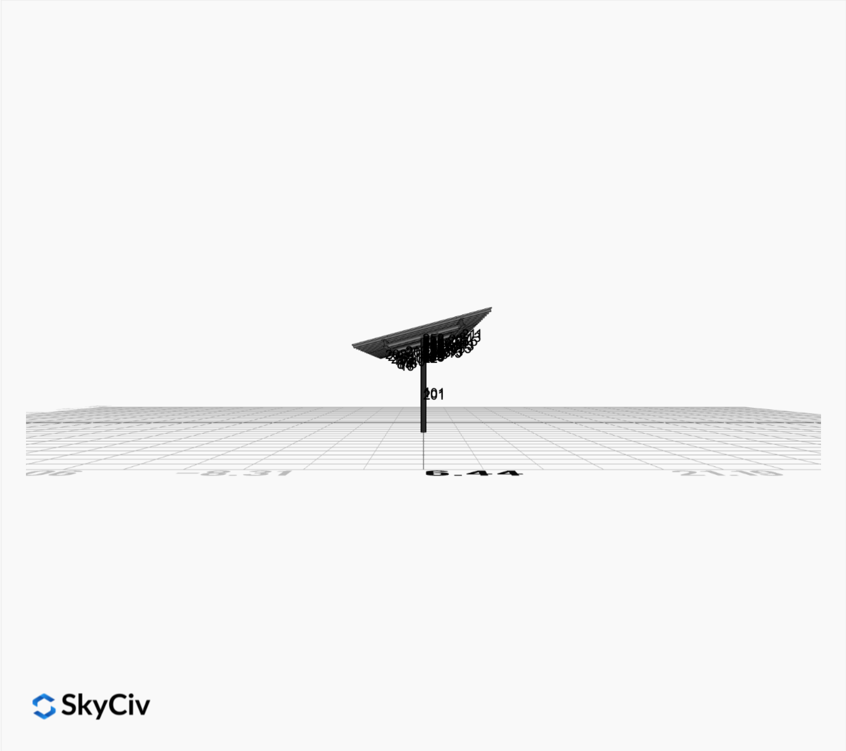
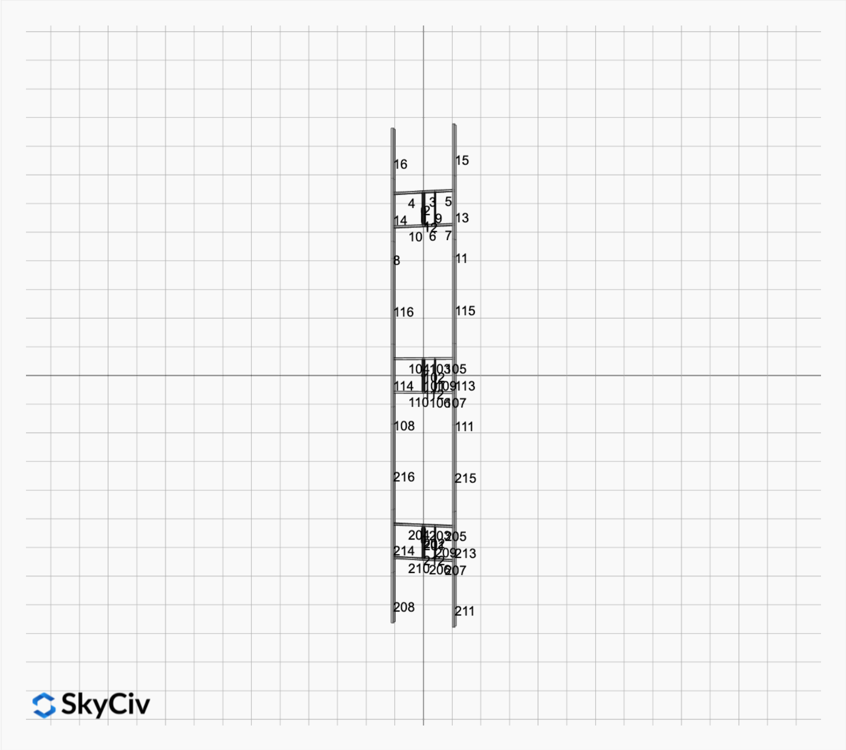
**Design Notes:**

- AISC Deflection checks are set to L/1 due to structure design intent




201
SkyCiv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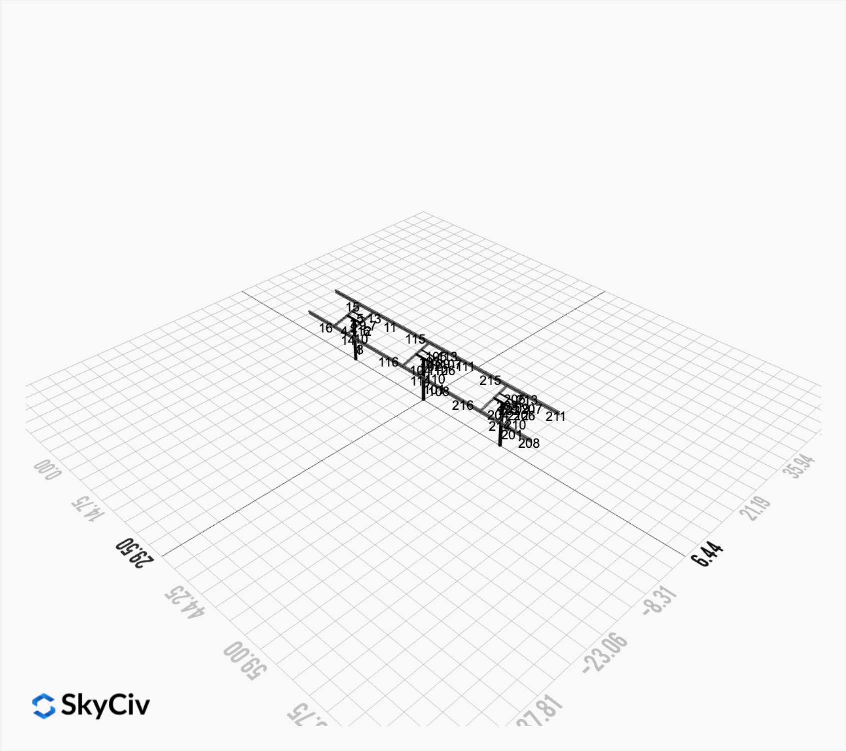
SkyCiv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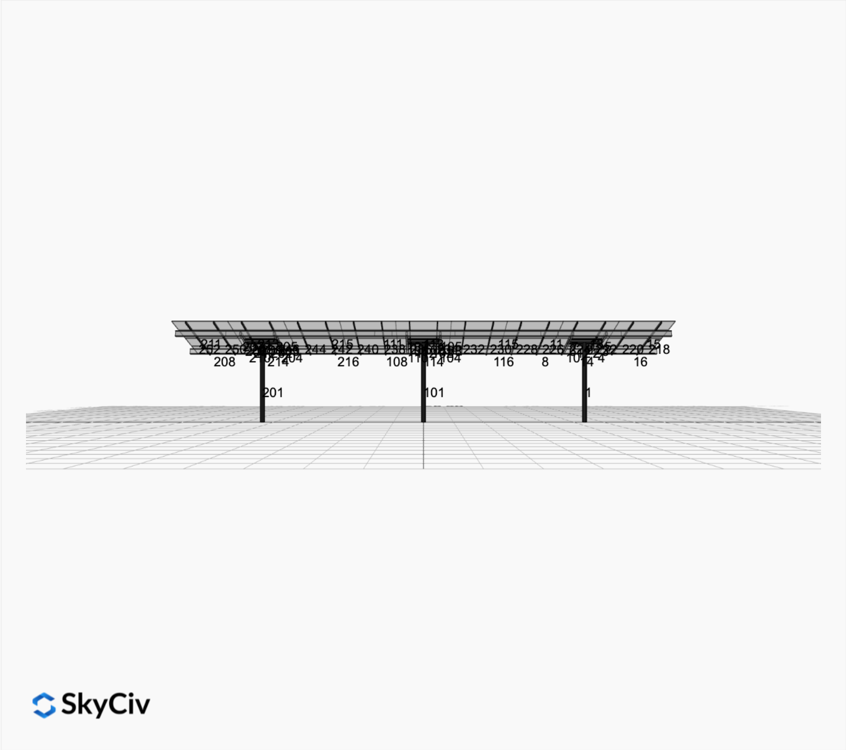
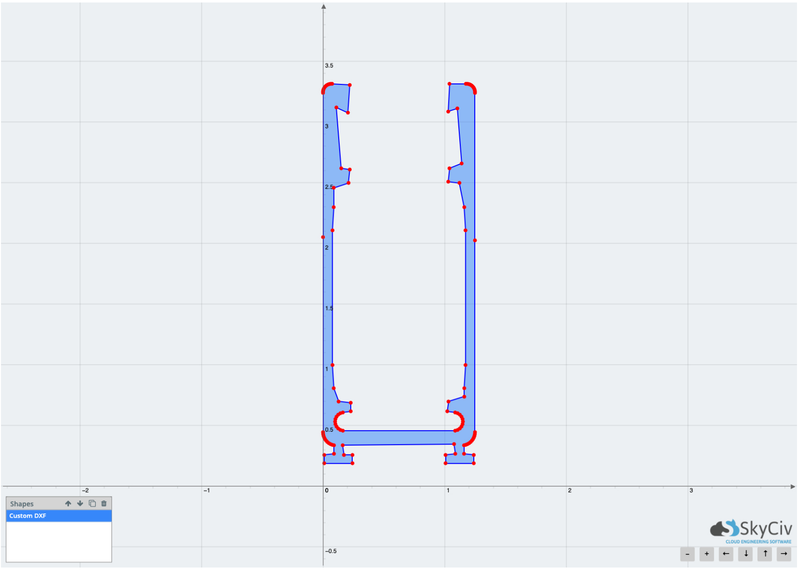
29.50
44.25
59.00
35.94
21.19
6.44
-8.31
-23.06

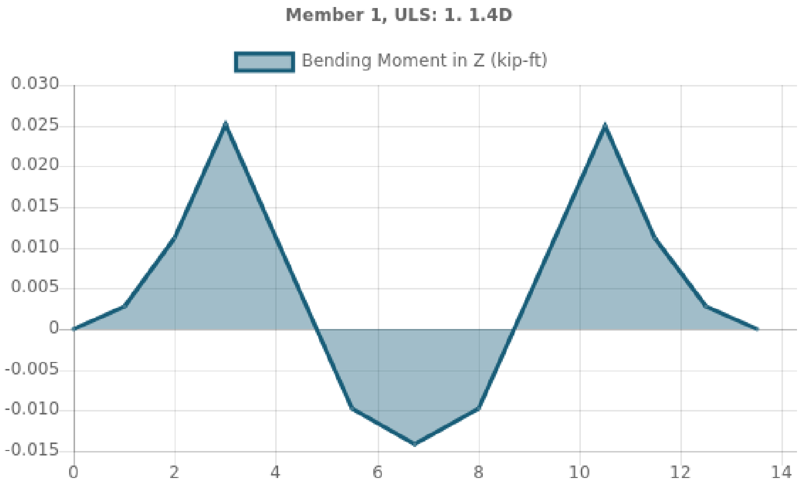


## Rail Design Check

**Rail Length:** 13.5 ft
**Additional Restraints Required:** None
**Tributary Width:** 3.2916666666666665 ft
**Material:** Aluminium
**Density:** 169 lb/ft$^3$
**Elasticity Modulus:** 10000 ksi
**Fy:** 34.5 ksi
**Fu:** 37 ksi
**Snow (X):** 0.0288 kip/ft
**Snow (Y):** -0.0077 kip/ft
**Wind uplift Case A:** 0.0709 kip/ft
**Wind uplift Case A:** 0.0709 kip/ft
**Wind uplift Case B (X):** 0.0000 kip/ft
**Wind uplift Case B (Y):** 0.1036 kip/ft




| Result Check | Max Limit | Max Value | Utility | Status |
|---|---|---|---|---|
| Custom Stress Limit | 34.5 | 9.75203233 | 0.283 | PASS |
| Material Yield | 34.5 | 9.75203233 | 0.283 | PASS |
| Material Strength | 37 | 9.75203233 | 0.264 | PASS |



## 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 | -0.0116 | 2.0904 | -0.0473 | -0.1405 | 0.0267 | 0.1219 |
| ULS: 2. D + L | -0.0116 | 2.0904 | -0.0473 | -0.1405 | 0.0267 | 0.1219 |
| ULS: 3. D + (S or Lr or R) | -0.0280 | 4.4888 | -0.1141 | -0.3392 | 0.0644 | 0.2572 |
| ULS: 3. D + (S or Lr or R) | -0.0116 | 2.0904 | -0.0473 | -0.1405 | 0.0267 | 0.1219 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0239 | 3.8892 | -0.0974 | -0.2896 | 0.0550 | 0.2234 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0116 | 2.0904 | -0.0473 | -0.1405 | 0.0267 | 0.1219 |
| ULS: 5b. D + 0.7E | -0.0116 | 2.0904 | -0.0473 | -0.1405 | 0.0267 | 0.1219 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0239 | 3.8892 | -0.0974 | -0.2896 | 0.0550 | 0.2234 |
| ULS: 8. 0.6D + 0.7E | -0.0070 | 1.2543 | -0.0284 | -0.0843 | 0.0160 | 0.0731 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.0307 | 5.9246 | -0.1610 | -0.4778 | 0.1087 | 11.9730 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -1.0307 | 5.9246 | -0.1610 | -0.4778 | 0.1087 | 11.9730 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.7647 | -0.8201 | 0.0361 | 0.1056 | -0.0324 | -5.2707 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.6501 | -0.4177 | 0.0316 | 0.0921 | -0.0324 | -15.4337 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.7882 | 6.7648 | -0.1827 | -0.5425 | 0.1165 | 9.1117 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.7882 | 6.7648 | -0.1827 | -0.5425 | 0.1165 | 9.1117 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5584 | 1.7063 | -0.0349 | -0.1050 | 0.0107 | -3.8210 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.4724 | 2.0081 | -0.0382 | -0.1150 | 0.0106 | -11.4433 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.7759 | 4.9661 | -0.1326 | -0.3935 | 0.0882 | 9.0102 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.7759 | 4.9661 | -0.1326 | -0.3935 | 0.0882 | 9.0102 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5707 | -0.0925 | 0.0152 | 0.0440 | -0.0176 | -3.9225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.4847 | 0.2093 | 0.0119 | 0.0340 | -0.0176 | -11.5448 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.0261 | 5.0885 | -0.1421 | -0.4216 | 0.0980 | 11.9243 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -1.0261 | 5.0885 | -0.1421 | -0.4216 | 0.0980 | 11.9243 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.7694 | -1.6563 | 0.0550 | 0.1618 | -0.0431 | -5.3194 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.6548 | -1.2539 | 0.0506 | 0.1484 | -0.0431 | -15.4825 |

### 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 | 10.0977 |
| Shear X | -1.7198 |
| Shear Z | -0.2807 |
| Moment X | -0.8350 |
| Moment Y (Twist) | 0.1883 |
| Moment Z | 26.4022 |

### 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 | 6.7648 |
| Shear X | -1.0307 |
| Shear Z | -0.1827 |
| Moment X | -0.5425 |
| Moment Y (Twist) | 0.1165 |
| Moment Z | 15.4825 |

## 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 | 0.0232 | 1.9378 | -0.0000 | 0.0000 | -0.0000 | -0.1571 |
| ULS: 2. D + L | 0.0232 | 1.9378 | -0.0000 | 0.0000 | -0.0000 | -0.1571 |
| ULS: 3. D + (S or Lr or R) | 0.0560 | 4.1208 | -0.0000 | 0.0000 | -0.0000 | -0.4169 |
| ULS: 3. D + (S or Lr or R) | 0.0232 | 1.9378 | -0.0000 | 0.0000 | -0.0000 | -0.1571 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0478 | 3.5751 | -0.0000 | 0.0000 | -0.0000 | -0.3519 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0232 | 1.9378 | -0.0000 | 0.0000 | -0.0000 | -0.1571 |
| ULS: 5b. D + 0.7E | 0.0232 | 1.9378 | -0.0000 | 0.0000 | -0.0000 | -0.1571 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0478 | 3.5751 | -0.0000 | 0.0000 | -0.0000 | -0.3519 |
| ULS: 8. 0.6D + 0.7E | 0.0139 | 1.1627 | -0.0000 | 0.0000 | -0.0000 | -0.0943 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -0.9218 | 5.4031 | -0.0000 | 0.0000 | -0.0000 | 10.9823 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.9218 | 5.4031 | -0.0000 | 0.0000 | -0.0000 | 10.9823 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.7337 | -0.6872 | -0.0000 | 0.0000 | -0.0000 | -5.1349 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.6543 | -0.3403 | -0.0000 | 0.0000 | -0.0000 | -15.0599 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.6610 | 6.1741 | -0.0000 | 0.0000 | -0.0000 | 8.0026 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.6610 | 6.1741 | -0.0000 | 0.0000 | -0.0000 | 8.0026 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5806 | 1.6063 | -0.0000 | 0.0000 | -0.0000 | -4.0853 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.5211 | 1.8665 | -0.0000 | 0.0000 | -0.0000 | -11.5290 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.6855 | 4.5368 | -0.0000 | 0.0000 | -0.0000 | 8.1975 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.6855 | 4.5368 | -0.0000 | 0.0000 | -0.0000 | 8.1975 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5561 | -0.0310 | -0.0000 | 0.0000 | -0.0000 | -3.8904 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.4965 | 0.2292 | -0.0000 | 0.0000 | -0.0000 | -11.3342 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -0.9311 | 4.6280 | -0.0000 | 0.0000 | -0.0000 | 11.0452 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.9311 | 4.6280 | -0.0000 | 0.0000 | -0.0000 | 11.0452 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.7244 | -1.4624 | -0.0000 | 0.0000 | -0.0000 | -5.0720 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.6450 | -1.1154 | -0.0000 | 0.0000 | -0.0000 | -14.9970 |

### 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 | 9.1930 |
| Shear X | -1.5751 |
| Shear Z | -0.0000 |
| Moment X | 0.0001 |
| Moment Y (Twist) | 0.0001 |
| Moment Z | 25.8027 |

### 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 | 6.1741 |
| Shear X | -0.9311 |
| Shear Z | -0.0000 |
| Moment X | 0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 15.0599 |

## 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 | -0.0116 | 2.0904 | 0.0473 | 0.1406 | -0.0267 | 0.1219 |
| ULS: 2. D + L | -0.0116 | 2.0904 | 0.0473 | 0.1406 | -0.0267 | 0.1219 |
| ULS: 3. D + (S or Lr or R) | -0.0280 | 4.4888 | 0.1141 | 0.3392 | -0.0645 | 0.2572 |
| ULS: 3. D + (S or Lr or R) | -0.0116 | 2.0904 | 0.0473 | 0.1406 | -0.0267 | 0.1219 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0239 | 3.8892 | 0.0974 | 0.2896 | -0.0550 | 0.2234 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0116 | 2.0904 | 0.0473 | 0.1406 | -0.0267 | 0.1219 |
| ULS: 5b. D + 0.7E | -0.0116 | 2.0904 | 0.0473 | 0.1406 | -0.0267 | 0.1219 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0239 | 3.8892 | 0.0974 | 0.2896 | -0.0550 | 0.2234 |
| ULS: 8. 0.6D + 0.7E | -0.0070 | 1.2543 | 0.0284 | 0.0843 | -0.0160 | 0.0731 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.0307 | 5.9246 | 0.1610 | 0.4778 | -0.1087 | 11.9730 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -1.0307 | 5.9246 | 0.1610 | 0.4778 | -0.1087 | 11.9730 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 0.7647 | -0.8201 | -0.0361 | -0.1056 | 0.0324 | -5.2707 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.6501 | -0.4177 | -0.0316 | -0.0921 | 0.0324 | -15.4337 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.7882 | 6.7648 | 0.1827 | 0.5425 | -0.1165 | 9.1117 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.7882 | 6.7648 | 0.1827 | 0.5425 | -0.1165 | 9.1117 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5584 | 1.7063 | 0.0349 | 0.1050 | -0.0107 | -3.8210 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.4724 | 2.0081 | 0.0382 | 0.1151 | -0.0107 | -11.4433 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---|---|---|---|---|---|
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.7759 | 4.9661 | 0.1326 | 0.3935 | -0.0882 | 9.0102 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.7759 | 4.9661 | 0.1326 | 0.3935 | -0.0882 | 9.0102 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.5707 | -0.0925 | -0.0152 | -0.0440 | 0.0176 | -3.9225 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.4847 | 0.2093 | -0.0119 | -0.0340 | 0.0176 | -11.5448 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.0261 | 5.0885 | 0.1421 | 0.4216 | -0.0980 | 11.9243 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -1.0261 | 5.0885 | 0.1421 | 0.4216 | -0.0980 | 11.9243 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 0.7694 | -1.6563 | -0.0550 | -0.1618 | 0.0431 | -5.3194 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.6548 | -1.2539 | -0.0506 | -0.1483 | 0.0431 | -15.4825 |

### 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 | 10.0977 |
| Shear X | -1.7198 |
| Shear Z | 0.2807 |
| Moment X | 0.8350 |
| Moment Y (Twist) | 0.1883 |
| Moment Z | 26.4028 |

### 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 | 6.7648 |
| Shear X | -1.0307 |
| Shear Z | 0.1827 |
| Moment X | 0.5425 |
| Moment Y (Twist) | 0.1165 |
| Moment Z | 15.4825 |

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

## Wind Load Calculations based on ASCE 7-16

**Design Information :**

Project Name : NMSUAgro-JB-RevB1
Client :
Designer : MT_SKYCIV AutoDesigner
Company : MT Solar
Units : Imperial
Notes : Snow loads based on monoslope structure

**Project Data**

The structure is located in **150 N William Dillard Dr, Gilbert, AZ 85233, USA** categorized as **Exposure C** (assumed to be homogeneous for the s elected wind direction). The wind load calculation for the structure - Main Wind Force Resisting System (MWFRS) - is based on the Directional Proced ure (Chapter 27) of ASCE 7. Morever, the structure is classified as **Risk Category I**. The location is elevated at **1218.19 ft** above mean sea level.

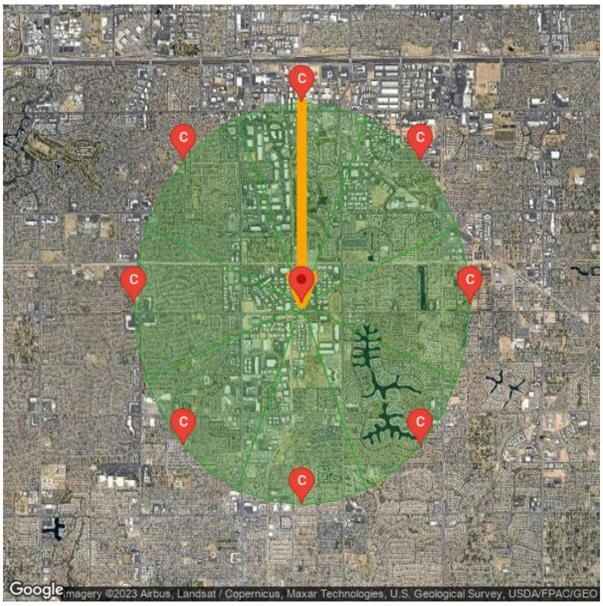



**Figure 1. Site location.**

| Parameter | Value |
| --- | --- |
| Building Length, $L$ | 12.88 ft |
| Building Width, $B$ | 59.00 ft |
| Mean Roof Height, $h$ | 9.75 ft |
| Roof Profile | Open Monoslope |
| Roof Pitch Angle, $\theta$ | 15.00° |
| Structure Type | Main Wind Force Resisting System (MWFRS) |
| Wind Blockage | Empty Under |

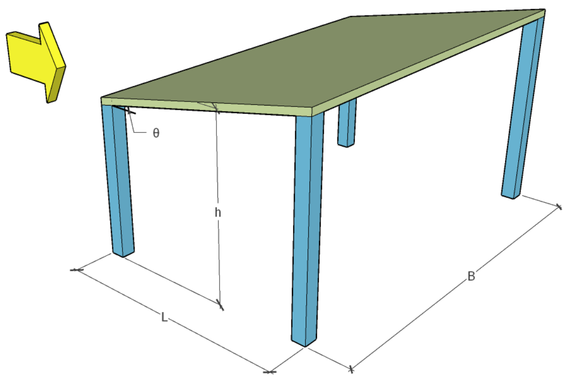



**Figure 2. Building parameters.**

| REFERENCES | CALCULATIONS | RESULTS |
| --- | --- | --- |
| *Figure 26.5-1* | **Basic Wind Speed, $V$**<br>Wind speed for the address is **105 mph (defined by the user)** for Risk Category I and was calculated using Triangular Interpolation Network (TIN) method from points with known wind speed values based on Figure 26.5-1 of ASCE 7. | $V = 105$ mph **(defined by the user)** |
| *Table 26.6-1* | **Wind Directionality Factor, $K_d$**<br>$K_d = 0.85$ - Wind Directionality Factor<br>*For buildings* | $K_d = 0.85$ |
| | **Topographic Factor, $K_{zt}$** | |


SkyCiv

| | | |
|---|---|---|
| *Section 26.8.1* | $K_{zt} = 1$ - Topographic Factor<br>*For the selected wind source direction, either the terrain is relatively a flat surface or the structure is outside the local topographic zones.*<br>**For calculating the topographic factor, the detected topography for the selected wind source direction is Flat.** | $K_{zt} = 1$ |

**Ground Elevation Factor, $K_e$**

*Section 26.9* $K_e$ - Ground Elevation Factor

$$K_e = e^{-0.0000362\ E}$$

$$K_e = 0.95686$$

$$\text{Where } E = \text{Site Elevation} = 1218.2 \text{ ft}$$

*Section 26.9* $K_e = 0.95686$ - Ground Elevation Factor — $K_e = 0.95686$

**Velocity Pressure Exposure Coefficient, $K_z$**

*Section 26.10* $K_z$ - Velocity Pressure Exposure Coefficient

*For $z < 15ft$*

$$K_z = 2.01 \times (15/z_g)^{2/\alpha}$$

*Section 26.10* $K_z$ - Velocity Pressure Exposure Coefficient

*For $15ft \leq z \leq z_g$*

$$K_z = 2.01 \times (z/z_g)^{2/\alpha}$$

*Section 26.10* $K_z$ - Velocity Pressure Exposure Coefficient

*For $z < 15ft$*

$$K_z = 2.01\ (15/z_g)^{2/\alpha}$$

$$K_z = 0.84888$$

$$\text{Where } z_g = 900$$
$$\alpha = 9.5$$

| Level | Elevation $(ft)$ | $K_z$ |
|---|---|---|
| h | 9.747 | 0.849 |

**Velocity Pressure, $q_h$**

For the selected wind source direction.

*Section 26.10.2* $q_h$ - Velocity Pressure at h

$$q_h = 0.00256\ K_z\ K_{zt}\ K_d\ K_e\ V^2$$

$$q_h = 19.487 \text{ psf}$$

$$\text{Where } K_z = \text{Velocity Pressure Exposure Coefficient} = 0.84888$$
$$K_{zt} = \text{Topographic Factor} = 1$$
$$K_d = \text{Wind Directionality Factor} = 0.85$$
$$V = \text{Basic Wind Speed} = 105 \text{ mi/h}$$
$$K_e = \text{Ground Elevation Factor} = 0.95686$$

**Velocity Pressure for All Directions**

*Section 26.8* $K_{zt}$ - Topographic Factor

$$K_{zt} = (1 + K_1 \times K_2 \times K_3)^2$$

*Section 26.10* $K_z$ - Velocity Pressure Exposure Coefficient

*For $15ft \leq z \leq z_g$*

$$K_z = 2.01 \times (z/z_g)^{2/\alpha}$$

*Section 26.10* $K_z$ - Velocity Pressure Exposure Coefficient

*For $z < 15ft$*

$$K_z = 2.01 \times (15/z_g)^{2/\alpha}$$

| Direction | Exposure Category | $K_z$ @ $h = 9.747ft$ | $K_{zt}$ | $K_e$ | $V$ $(mph)$ | $q_h$ $(psf)$ |
|---|---|---|---|---|---|---|
| N | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| NE | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| E | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| SE | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| S | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| SW | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| W | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |
| NW | C | 0.849 | 1.000 | 0.957 | 105.000 | 19.487 |

**Net Pressure Coefficients, $C_N$**

*Figure 27.3-4 to 27.3-7* The net pressure coefficients, $C_N$, are calculated using Figures 27.3-4 to 27.3-7 of ASCE 7-16 - Clear Wind Flow - as shown in Table below.

| Direction | Surface | $C_N$ Case A | $C_N$ Case B |
|---|---|---|---|
| 0 | Windward | -0.900 | -1.900 |
| | Leeward | -1.300 | - |
| 180 | Windward | 1.300 | 1.800 |
| | Leeward | 1.600 | 0.600 |
| 90 | ≤ h from windward edge | -0.800 | 0.800 |
| | h to 2h from windward edge | -0.600 | 0.500 |
| | > 2h from windward edge | -0.300 | 0.300 |

| | | | |
|---|---|---|---|
| Section 26.11.1 | **Gust Effect Factor, $G$**<br>$G = 0.85$ - Gust Effect Factor<br>*The structure is assumed to be rigid.* | $G = 0.85$ |

Section 27.3.2

**Design Wind Pressures (MWFRS)**

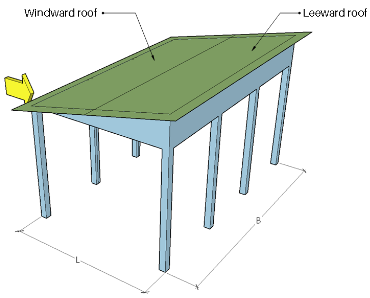
$p$ - Design Wind Pressure

*For open buildings*

$$p = q_h \times G \times C_N$$

**For Wind Pressure - 0°**

| Direction | Surface | $q_h$ $(psf)$ | $G$ | $C_N$ Case A | $C_N$ Case B | $p$ Case A $(psf)$ | $p$ Case B $(psf)$ |
|---|---|---|---|---|---|---|---|
| 0 | Windward | 19.487 | 0.850 | -0.900 | -1.900 | -14.907 | -31.471 |
| | Leeward | 19.487 | 0.850 | -1.300 | - | -21.533 | 0.000 |
| 180 | Windward | 19.487 | 0.850 | 1.300 | 1.800 | 21.533 | 29.814 |
| | Leeward | 19.487 | 0.850 | 1.600 | 0.600 | 26.502 | 9.938 |



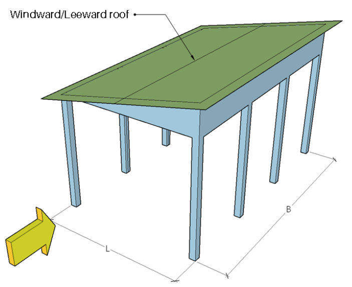

**Wind along L - 0°**

**Service Wind Pressure - 0°/180°**

| Direction | Surface | $p$ Case A $(psf)$ | $p$ Case B $(psf)$ |
|---|---|---|---|
| 0 | Windward | -8.944 | -18.882 |
| | Leeward | -12.920 | 0.000 |
| 180 | Windward | 12.920 | 17.889 |
| | Leeward | 15.901 | 5.963 |

**For Wind Pressure - 90°**

| Direction | Surface | $q_h$ $(psf)$ | $G$ | $C_N$ Case A | $C_N$ Case B | $p$ Case A $(psf)$ | $p$ Case B $(psf)$ |
|---|---|---|---|---|---|---|---|
| 90 | ≤ h from windward edge | 19.487 | 0.850 | -0.800 | 0.800 | -13.251 | 13.251 |
| | h to 2h from windward edge | 19.487 | 0.850 | -0.600 | 0.500 | -9.938 | 8.282 |
| | > 2h from windward edge | 19.487 | 0.850 | -0.300 | 0.300 | -4.969 | 4.969 |




**Wind along B - 90°**

**Service Wind Pressure - 90°**

| Direction | Surface | $p$ Case A $(psf)$ | $p$ Case B $(psf)$ |
|---|---|---|---|
| 90 | ≤ h from windward edge | -7.950 | 7.950 |
| | h to 2h from windward edge | -5.963 | 4.969 |
| | > 2h from windward edge | -2.981 | 2.981 |

| | | |
|---|---|---|
| *Section 27.3.2*<br>*Section 28.3.5* | In addition to the roof pressures for 90°, an additional horizontal wind load on open building should be calculated for wind pressures parallel to the ridge in accordance with Section 28.3.5. We will assume $K_S = 1.0$ and should be adjusted and be reduced based on the actual solidity ratio $\phi$ and number of frames $n$ - See Figure 28.3-2. | |
| *Section 27.3.2*<br>*Section 28.3.5* | $p$ - Horizontal Wind Loads on Open or Partially Enclosed Buildings<br>*For wind pressure parallel to the ridge (90°)*<br>$$p = q_h \times [(GC_{pf})_{windward} - (GC_{pf})_{leeward}] \times K_B \times K_S$$ | |
| *Section 27.3.2*<br>*Section 28.3.5* | $K_B$ - Frame Width Factor<br>*For* $L < 100ft$, $K_B = 1.8 - 0.01L$. *Otherwise,* $K_B = 0.8$.<br>$$K_B = 1.8 - 0.01 * L \leq 0.8$$<br>$$K_B = 1.6712$$<br>$$\text{Where } L = \text{Building Length} = 12.879 \text{ ft}$$ | |
| *Section 28.3.5* | $K_S$ - Shielding Factor<br>$$K_S = 0.6 + 0.073 \times (n-1) + \left(1.25 \times \phi^{1.8}\right)$$ | |
| *Section 28.3.5* | $K_S = 1$ - Shielding Factor<br>*Assumed to be equal to 1.0 and should be adjusted based on the actual wall solidity ratio* $\phi$ *and number of frames* $n$. | $K_S = 1$ |
| *Figure 28.3-1*<br>*Section 28.3.5* | $(GC_{pf})_{windward} = 0.4$<br>*Using Zone 5 from Figure 28.3-1* | $(GC_{pf})_{windward} = 0.4$ |
| *Figure 28.3-1*<br>*Section 28.3.5* | $(GC_{pf})_{leeward} = -0.29$<br>*Using Zone 6 from Figure 28.3-1* | $(GC_{pf})_{leeward} = -0.29$ |
| *Section 27.3.2*<br>*Section 28.3.5* | $p$ - Horizontal Wind Loads on Open or Partially Enclosed Buildings<br>*For wind pressure parallel to the ridge (90°)*<br>$$p = q_h \ [(GC_{pf})_{windward} - (GC_{pf})_{leeward}] \ K_B \ K_S$$<br>$$p = 22.471 \text{ psf}$$ | |

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

## Snow Load Detailed Calculations based on ASCE 7-16

### Design Information :

Project Name : NMSUAgro-JB-RevB1
Client :
Designer : MT_SKYCIV AutoDesigner
Company : MT Solar
Units : Imperial
Notes : Snow loads based on monoslope structure

### Project Data

The structure is located in **150 N William Dillard Dr, Gilbert, AZ 85233, USA** categorized as **Risk Category I**. The snow l oad calculation for the structure is based on the Snow Loads (Chapter 7) of ASCE 7. The location is elevated at **1218 ft** above mean sea level.

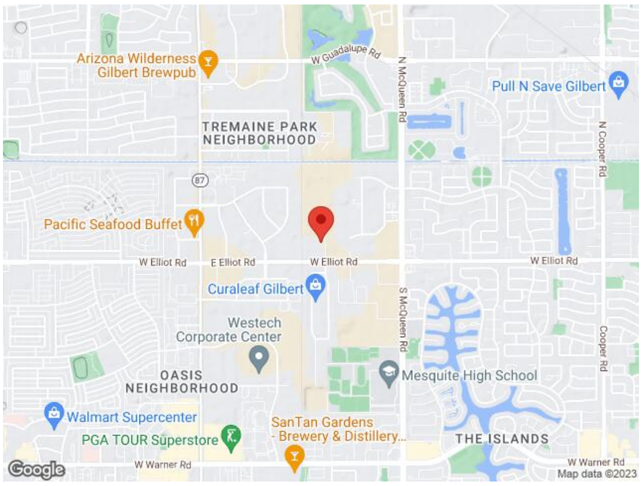



**Figure 1. Site location.**

Additional details of the structure are shown in Table below and illustrated in Figure 2:

| Parameter | Value |
|---|---|
| Building Length, $L$ | 12.879 ft |
| Building Width, $B$ | 59.000 ft |
| Mean Roof Height, $h$ | 9.747 ft |
| Roof Profile | Open Monoslope |
| Roof Pitch Angle, $\theta$ | 15.000° |

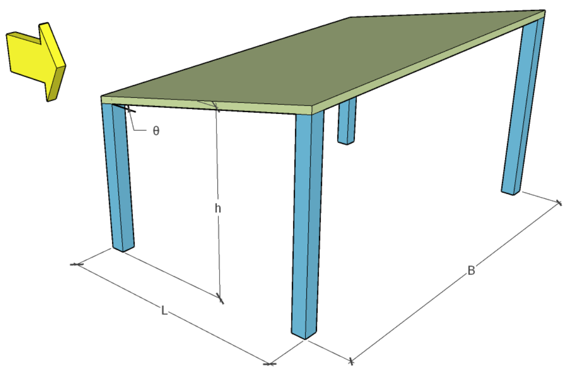



**Figure 2. Building parameters.**

### Ground Snow Load, $p_g$

Section 7.2 of ASCE 7

The ground snow load, $p_g$, for the site location is **15 psf (defined by the user)** at elevation 1218.19 ft above mean sea leve

$p_g$ = 15 psf **(defined b**

| | | |
|---|---|---|
| | The ground snow load, $p_g$, for the site location is **15 psf (defined by the user)** at elevation 1218.19 ft above mean sea level based on Section 7.2 of ASCE 7. | $p_g = 15$ psf **(defined by the user)** |
| Table 7-2 Section 7.3.1 of ASCE 7 | **Exposure Factor, $C_e$**<br>The exposure factor, $C_e$, for the structure is equal $0.90$ as the terrain is categorized as **Exposure C** with exposure condition specified as **Fully Exposed** based on Table 7-2 Section 7.3.1 of ASCE 7. | $C_e = 0.90$ |
| Table 7-3 Section 7.3.2 of ASCE 7 | **Thermal Factor, $C_e$**<br>Since the thermal condition of the structure is categorzied as **"Unheated and open air structures,"** the corresponding thermal factor, $C_t$, is equal $1.20$ based on Table 7-3 Section 7.3.2 of ASCE 7. | $C_t = 1.20$ |
| Table 1.5-2 of Chapter 1 ASCE 7 | **Importance Factor, $I_s$**<br>Since the structure is classified Risk Category I, the Importance Factor, $I_s$, is equal to **0.8**. | $I_s = 0.80$ |
| Equation 7.3-1 of Section 7.3 ASCE 7 | **Flat Roof Snow Load, $p_f$**<br>The flat roof snow load, $p_f$, (psf) is calculated using the Equation 7.3-1:<br>$$p_f = 0.7 C_e C_t I_s p_g$$<br>$$p_f = 0.7(0.90)(1.20)(0.80)(15.00) = 9.07 psf$$ | $p_f = 9.07$ psf |
| Section 7.10 ASCE 7 | **Rain-on-snow Surcharge Load, $p_r$**<br>The rain-on-snow surcharge load, $p_r$, is equal to 0.00 psf since $p_g$ ≤ 20 psf but not zero. This is in addition to the sloped roof (balanced) load case. | $p_r = 0.00$ psf |
| Equation 7.7-1 of ASCE 7 | **Snow Density, $\gamma$**<br>The snow density, $\gamma$, is calculated using Equation 7.7-1 of ASCE 7 as:<br>$$\gamma = 0.13 p_g + 14 \leq 30 = 0.13(15.00) + 14 \leq 30$$<br>$$\gamma = 15.95 pcf$$ | $\gamma = 15.95 pcf$ |
| Section 7.4 ASCE 7 | **Roof Slope Factor (Balanced), $C_s$**<br>Since the roof is classified as cold roof ($C_t > 1.0$), the corresponding roof slope factor, $C_s$, is equal to 1.000 based on Figure 7.2c where $\theta = 15.00°$. | $C_s = 1.000$ |
| Equation 7.4-1 of Section 7.4 ASCE 7 | **Sloped Roof Snow Load (Balanced), $p_s$**<br>The sloped roof snow load, $p_s$, (psf) is calculated using the Equation 7.4-1:<br>$$p_s = C_s p_f$$<br>$$p_s = (1.000)(9.07) = 9.07 psf$$ | $p_s = 9.07$ psf |

## Project Details

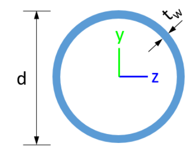
| | |
|---|---|
| Design Code: | AISC 360-16 LRFD |
| Provision: | LRFD |
| Country: | United States |
| User Name: | sales@mtsolar.us |
| Project Name: | NMSUAgro-JB-RevB1 |
| Unit System: | imperial |

## Design Input Information

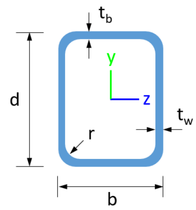
| Design Factors | | | |
|---|---|---|---|
| $\Phi_t$ | $\Phi_c$ | $\Phi_b$ | $\Phi_v$ |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

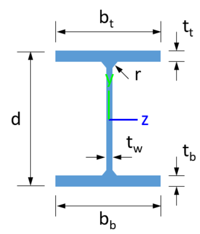
**Section Dimensions**




| ID | Name | d (in) | $t_w$ (in) |
|---|---|---|---|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 |
| 7 | 6in Pipe Sch 40 | 6.63 | 0.28 |




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




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

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | 6in Pipe Sch 40 | 5.58 | 56.28 | 28.14 | 28.14 | 0.00 | 11.28 | 11.28 |
| 16 | HSS5x3x3/16 | 2.58 | 8.64 | 3.85 | 8.53 | 92.39 | 2.96 | 4.21 |
| 19 | W8x10 | 2.96 | 0.04 | 2.09 | 30.80 | 30.90 | 1.66 | 8.87 |

| **Member Properties** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Member ID | Section ID | $K_zL$ (ft) | $K_yL$ (ft) | $L_b$(ft) | $C_b$ | LST | LSC | LD |
| 1 | 7 | 20.47 | 20.47 | 9.75 | - | 300 | 200 | 1 |
| 2 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 3 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.24,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 4 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.68,1.67,1.67,1.66,1.69 | 300 | 200 | 1 |
| 5 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.35,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 6 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,2.03,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 7 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.23,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 8 | 19 | 1.33 | 1.33 | 2.05 | 1.85,1.85,1.85,1.85,1.85,1.85,1.84,1.84,1.86,1.95,1.84,1.84,1.86,2.03,1.84,1.84,1.84,1.87,1.84,1.84,1.86,1.93,1.84,1.84,1.86,2.11 | 300 | 200 | 1 |
| 9 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 10 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.69,1.67,1.67,1.66,1.69 | 300 | 200 | 1 |
| 11 | 19 | 1.33 | 1.33 | 2.05 | 1.87,1.87,1.87,1.87,1.87,1.87,1.87,1.87,1.80,1.91,1.87,1.87,1.84,1.90,1.87,1.87,1.88,1.80,1.87,1.87,1.62,1.91,1.87,1.87,1.84,1.90 | 300 | 200 | 1 |
| 12 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 13 | 19 | 4.88 | 4.00 | 7.50 | 1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.16,1.08,1.08,1.09,1.15,1.09,1.09,1.09,1.09,1.08,1.08,1.11,1.18,1.08,1.08,1.09,1.14 | 300 | 200 | 1 |
| 14 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.22,1.08,1.08,1.08,1.35,1.08,1.08,1.09,1.09,1.08,1.08,1.12,1.18,1.08,1.08,1.08,1.49 | 300 | 200 | 1 |
| 15 | 19 | 12.60 | 12.60 | 6.00 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 16 | 19 | 12.60 | 12.60 | 6.00 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 101 | 7 | 20.47 | 20.47 | 9.75 | - | 300 | 200 | 1 |
| 102 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 103 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,2.30,1.17,1.18,1.18,1.17,1.18 | 300 | 200 | 1 |
| 104 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.62,1.69,1.67,1.67,1.66,1.68 | 300 | 200 | 1 |
| 105 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.13,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 106 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,2.30,1.17,1.18,1.18,1.17,1.18 | 300 | 200 | 1 |
| 107 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.13,1.66,1.67,1.67,1.66,1.66 | 30 | 20 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | [illegible] | 0 | 0 | |
| 108 | 19 | 1.33 | 1.33 | 2.05 | 1.85,1.86,1.85,1.86,1.85,1.85,1.81,1.81,2.05,2.35,1.81,1.81,2.04,2.19,1.83,1.83,1.76,2.05,1.82,1.82,2.06,2.28,1.80,1.80,2.03,1.82 | 300 | 200 | 1 |
| 109 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 110 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.62,1.69,1.67,1.67,1.66,1.68 | 300 | 200 | 1 |
| 111 | 19 | 1.33 | 1.33 | 2.05 | 2.06,2.06,2.06,2.06,2.06,2.06,2.06,2.06,1.63,2.38,2.06,2.06,1.88,2.19,2.06,2.06,2.07,1.47,2.06,2.06,1.13,2.37,2.06,2.06,1.93,2.13 | 300 | 200 | 1 |
| 112 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.07,1.04,1.04,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.04,1.55,1.09,1.04,1.04,1.04,1.04 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.13,1.05,1.05,1.05,1.22,1.05,1.05,1.05,1.04,1.05,1.05,1.05,1.09,1.05,1.05,1.05,1.30 | 300 | 200 | 1 |
| 115 | 19 | 6.63 | 6.63 | 10.20 | 1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.17,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.13,1.15,1.15,1.13,1.17,1.15,1.15,1.15,1.16 | 300 | 200 | 1 |
| 116 | 19 | 6.63 | 6.63 | 10.20 | 1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.18,1.14,1.14,1.15,1.23,1.14,1.14,1.14,1.15,1.14,1.14,1.15,1.16,1.14,1.14,1.15,1.39 | 300 | 200 | 1 |
| 201 | 7 | 20.47 | 20.47 | 9.75 | - | 300 | 200 | 1 |
| 202 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,2.03,1.17,1.18,1.18,1.17,1.17 | 300 | 200 | 1 |
| 204 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.69,1.67,1.67,1.66,1.69 | 300 | 200 | 1 |
| 205 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.23,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 206 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.24,1.17,1.18,1.18,1.18,1.18 | 300 | 200 | 1 |
| 207 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.35,1.66,1.67,1.67,1.66,1.66 | 300 | 200 | 1 |
| 208 | 19 | 12.60 | 12.60 | 6.00 | 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 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.67,1.63,1.68,1.67,1.67,1.66,1.69 | 300 | 200 | 1 |
| 211 | 19 | 12.60 | 12.60 | 6.00 | 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 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 19 | 4.88 | 4.00 | 7.50 | 1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.16,1.08,1.08,1.09,1.15,1.09,1.09,1.09,1.09,1.08,1.08,1.11,1.18,1.08,1.08,1.09,1.14 | 300 | 200 | 1 |
| 214 | 19 | 4.88 | 4.00 | 7.50 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.22,1.08,1.08,1.08,1.35,1.08,1.08,1.09,1.09,1.08,1.08,1.12,1.18,1.08,1.08,1.08,1.49 | 300 | 200 | 1 |
| 215 | 19 | 6.63 | 6.63 | 10.20 | 1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.28,1.30,1.27,1.28,1.28,1.29,1.27,1.28,1.28,1.28,1.31,1.28,1.28,1.47,1.27,1.28,1.28,1.29,1.27 | 300 | 200 | 1 |
| 216 | 19 | 6.63 | 6.63 | 10.20 | 1.28,1.28,1.28,1.28,1.28,1.28,1.29,1.29,1.28,1.26,1.29,1.29,1.28,1.25,1.29,1.29,1.29,1.28,1.29,1.29,1.28,1.27,1.29,1.29,1.28,1.24 | 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 | 251.16 | 104.71 | 42.30 | 42.30 | 75.35 | 75.35 |
| 2 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 20.65 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 20.65 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 251.16 | 104.71 | 42.30 | 42.30 | 75.35 | 75.35 |
| 102 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 104 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 105 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 106 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 107 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 108 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 109 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 110 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 111 | 133.20 | 126.01 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 104.94 | 23.83 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 104.94 | 23.83 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 69.16 | 17.49 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 69.16 | 17.64 | 6.12 | 40.24 | 43.62 |
| 201 | 251.16 | 104.71 | 42.30 | 42.30 | 75.35 | 75.35 |
| 202 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 203 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 204 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 205 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 206 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 207 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 208 | 133.20 | 20.65 | 32.87 | 6.12 | 40.24 | 43.62 |
| 209 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 210 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 211 | 133.20 | 20.65 | 32.87 | 6.12 | 40.24 | 43.62 |
| 212 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 213 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 214 | 133.20 | 104.94 | 24.75 | 6.12 | 40.24 | 43.62 |
| 215 | 133.20 | 69.16 | 19.65 | 6.12 | 40.24 | 43.62 |
| 216 | 133.20 | 69.16 | 19.19 | 6.12 | 40.24 | 43.62 |

## Design Ratio

| Member ID | P | $M_z$ | $M_y$ | $V_y$ | $V_z$ | $(P,M_z,M_y)$ | Worst LC | KL/r | δ | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.096 | 0.624 | 0.045 | 0.023 | 0.004 | 0.629 | #32 | 0.547 | Not Required | Pass |
| 2 | 0.001 | 0.446 | 0.088 | 0.089 | 0.015 | 0.534 | #13 | 0.053 | Not Required | Pass |
| 3 | 0.003 | 0.667 | 0.028 | 0.068 | 0.003 | 0.688 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.004 | 0.582 | 0.071 | 0.059 | 0.014 | 0.590 | #13 | 0.080 | Not Required | Pass |
| 5 | 0.003 | 0.413 | 0.082 | 0.067 | 0.021 | 0.429 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.003 | 0.580 | 0.016 | 0.058 | 0.004 | 0.583 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.003 | 0.359 | 0.057 | 0.058 | 0.015 | 0.365 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.001 | 0.077 | 0.056 | 0.038 | 0.005 | 0.129 | #21 | 0.095 | Not Required | Pass |
| 9 | 0.007 | 0.085 | 0.032 | 0.002 | 0.001 | 0.118 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.003 | 0.509 | 0.070 | 0.051 | 0.016 | 0.550 | #13 | 0.080 | Not Required | Pass |
| 11 | 0.001 | 0.084 | 0.054 | 0.043 | 0.005 | 0.130 | #21 | 0.095 | Not Required | Pass |
| 12 | 0.002 | 0.360 | 0.079 | 0.077 | 0.014 | 0.440 | #13 | 0.035 | Not Required | Pass |
| 13 | 0.004 | 0.310 | 0.184 | 0.054 | 0.007 | 0.460 | #21 | 0.286 | Not Required | Pass |
| 14 | 0.003 | 0.284 | 0.184 | 0.048 | 0.007 | 0.442 | #21 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.141 | 0.110 | 0.038 | 0.005 | 0.236 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.122 | 0.110 | 0.033 | 0.005 | 0.227 | #21 | Not Required | Not Required | Pass |
| 101 | 0.088 | 0.610 | 0.000 | 0.021 | 0.000 | 0.611 | #16 | 0.547 | Not Required | Pass |
| 102 | 0.001 | 0.357 | 0.072 | 0.075 | 0.013 | 0.429 | #13 | 0.035 | Not Required | Pass |
| 103 | 0.003 | 0.573 | 0.021 | 0.058 | 0.004 | 0.586 | #13 | 0.045 | Not Required | Pass |
| 104 | 0.003 | 0.487 | 0.051 | 0.049 | 0.011 | 0.504 | #13 | 0.080 | Not Required | Pass |
| 105 | 0.003 | 0.355 | 0.052 | 0.057 | 0.013 | 0.360 | #13 | 0.074 | Not Required | Pass |
| 106 | 0.003 | 0.573 | 0.021 | 0.058 | 0.004 | 0.586 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.003 | 0.355 | 0.052 | 0.057 | 0.013 | 0.360 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.001 | 0.048 | 0.046 | 0.030 | 0.005 | 0.069 | #21 | 0.095 | Not Required | Pass |
| 109 | 0.004 | 0.055 | 0.016 | 0.001 | 0.000 | 0.071 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.003 | 0.487 | 0.051 | 0.049 | 0.011 | 0.504 | #13 | 0.080 | Not Required | Pass |
| 111 | 0.001 | 0.045 | 0.046 | 0.035 | 0.005 | 0.064 | #21 | 0.095 | Not Required | Pass |
| 112 | 0.001 | 0.357 | 0.072 | 0.075 | 0.013 | 0.429 | #13 | 0.035 | Not Required | Pass |
| 113 | 0.003 | 0.173 | 0.121 | 0.046 | 0.007 | 0.253 | #21 | 0.286 | Not Required | Pass |
| 114 | 0.003 | 0.137 | 0.121 | 0.039 | 0.007 | 0.223 | #21 | 0.286 | Not Required | Pass |
| 115 | 0.001 | 0.168 | 0.068 | 0.035 | 0.005 | 0.218 | #21 | 0.473 | Not Required | Pass |
| 116 | 0.001 | 0.158 | 0.068 | 0.030 | 0.005 | 0.217 | #21 | 0.473 | Not Required | Pass |
| 201 | 0.096 | 0.624 | 0.045 | 0.023 | 0.004 | 0.629 | #32 | 0.547 | Not Required | Pass |
| 202 | 0.002 | 0.360 | 0.079 | 0.077 | 0.014 | 0.440 | #13 | 0.035 | Not Required | Pass |
| 203 | 0.003 | 0.580 | 0.016 | 0.058 | 0.004 | 0.583 | #13 | 0.045 | Not Required | Pass |
| 204 | 0.003 | 0.509 | 0.070 | 0.051 | 0.016 | 0.550 | #13 | 0.080 | Not Required | Pass |
| 205 | 0.003 | 0.359 | 0.057 | 0.058 | 0.015 | 0.365 | #13 | 0.074 | Not Required | Pass |
| 206 | 0.003 | 0.667 | 0.028 | 0.068 | 0.003 | 0.688 | #13 | 0.045 | Not Required | Pass |
| 207 | 0.003 | 0.413 | 0.082 | 0.067 | 0.021 | 0.429 | #13 | 0.074 | Not Required | Pass |
| 208 | 0.000 | 0.122 | 0.110 | 0.033 | 0.005 | 0.227 | #21 | Not Required | Not Required | Pass |
| 209 | 0.007 | 0.085 | 0.032 | 0.002 | 0.001 | 0.118 | #13 | 0.204 | Not Required | Pass |
| 210 | 0.004 | 0.582 | 0.071 | 0.059 | 0.014 | 0.590 | #13 | 0.080 | Not Required | Pass |
| 211 | 0.000 | 0.141 | 0.110 | 0.038 | 0.005 | 0.236 | #21 | Not Required | Not Required | Pass |
| 212 | 0.001 | 0.446 | 0.088 | 0.089 | 0.015 | 0.534 | #13 | 0.053 | Not Required | Pass |
| 213 | 0.004 | 0.310 | 0.184 | 0.054 | 0.007 | 0.460 | #21 | 0.190 | Not Required | Pass |
| 214 | 0.003 | 0.284 | 0.184 | 0.048 | 0.007 | 0.442 | #21 | 0.286 | Not Required | Pass |
| 215 | 0.001 | 0.152 | 0.068 | 0.043 | 0.005 | 0.205 | #21 | 0.473 | Not Required | Pass |
| 216 | 0.001 | 0.139 | 0.069 | 0.038 | 0.005 | 0.200 | #21 | 0.473 | Not Required | Pass |

## Definitions

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

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

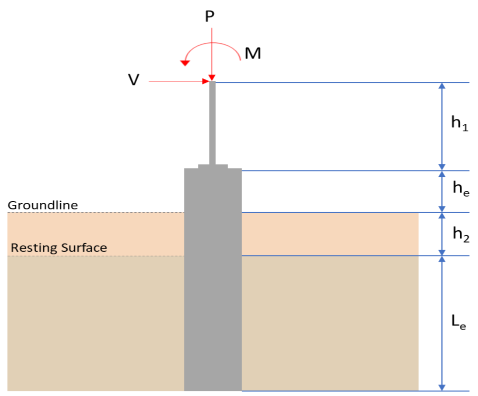
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 48\ \mathrm{in}$ - Pile diameter
$L = 6.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure $(q_a)$ $(\mathrm{psf})$ | Allowable Lateral Pressure $(R)$ $(\mathrm{psf/ft})$ |
|---|---|---|---|
| 1 | Sandy gravel and/or gravel | 3000.000 | 200.000 |

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.765 | 10.098 |
| $V_x$ (kip) | -1.031 | -1.720 |
| $V_z$ (kip) | -0.183 | -0.281 |
| $M_x$ (kipft) | -0.542 | -0.835 |
| $M_z$ (kipft) | 15.482 | 26.402 |

**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,

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

$$H_o = \frac{(-1.031\ \mathrm{kip})}{(48\ \mathrm{in})}$$

$$H_o = -0.25775\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(15.482\ \mathrm{kipft}) + ((-1.031\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(48\ \mathrm{in})}$$

$$M_o = 3.8705\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2996\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.183\ \mathrm{kip})}{(48\ \mathrm{in})}$$

$$H_o = -0.04575\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.542\ \mathrm{kipft}) + ((-0.183\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(48\ \mathrm{in})}$$

$$M_o = 0.1355\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.8833\ \mathrm{ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.2996\ \mathrm{ft}), (1.8833\ \mathrm{ft})]$$

$$L_{e,req} = 6.3\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.3\ \mathrm{ft})}{(6.75\ \mathrm{ft})}$$

$$Ratio = 0.93333$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

$$A = \pi \times \left(\frac{(48\ \mathrm{in})}{2}\right)^2$$

$$A = 12.566\ \mathrm{ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(6.765\ \mathrm{kip})}{(12.566\ \mathrm{ft}^2)}$$

$$q = 0.53834 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.53834 \text{ kip/ft}^2\right)}{(3000 \text{ psf})}$$

$$Ratio = 0.17945$$

Status: **PASS**
Ratio: **0.180**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.25775 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.8705 \text{ kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8705 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.25775 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (3.8705 \text{ kipft/ft})) + (4 \times (-0.25775 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6297 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (3.8705 \text{ kipft/ft})) + (3 \times (-0.25775 \text{ kip/ft}) \times (6.75 \text{ ft}))]^{\,2}}{(6.75 \text{ ft})^2 \times [(3 \times (3.8705 \text{ kipft/ft})) + (2 \times (-0.25775 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.33486 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (3.8705 \text{ kipft/ft})) + ((-0.25775 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 1.2414 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (200 \text{ psf/ft}) \times \frac{(4.6297 \text{ ft})}{2}$$

$$p_a = 0.46297 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.33486 \text{ kip/ft}^2\right)}{\left(0.46297 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.72328$$

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

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

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2414\ \mathrm{kip/ft^2}\right)}{(1.35\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.91955$$

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

**Considering z-direction:**

$H_o = -0.04575\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.1355\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1355\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.1355\ \mathrm{kipft/ft})) + (4 \times (-0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8392\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.1355\ \mathrm{kipft/ft})) + (3 \times (-0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.1355\ \mathrm{kipft/ft})) + (2 \times (-0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = -0.018099\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.1355\ \mathrm{kipft/ft})) + ((-0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = -0.0078218\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(4.8392\ \mathrm{ft})}{2}$$

$$p_a = 0.48392\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.018099\ \mathrm{kip/ft^2}\right)}{(0.48392\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.0374$$

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

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

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

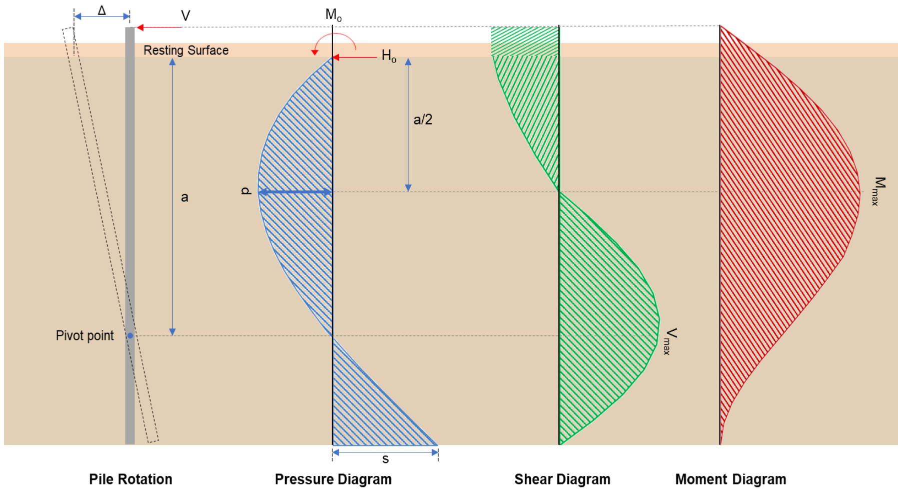
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(-0.0078218 \text{ kip/ft}^2\right)}{\left(1.35 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.005794$$

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




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-1.72 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -0.43 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(26.402 \text{ kipft}) + ((-1.72 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 6.6005 \text{ kipft/ft}$$

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

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

$$E = \frac{(6.6005 \text{ kipft/ft})}{(-0.43 \text{ kip/ft})}$$

$$E = 15.35 \text{ ft}$$

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

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

$$a = \frac{(4 \times (6.6005 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.43 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (6.6005 \text{ kipft/ft})) + (4 \times (-0.43 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6275 \text{ ft}$$

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

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

$$V_{max} = ((-0.43 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.35 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.6275 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.35 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.6275 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.0584 \text{ kip}$$

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

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

$$M_{max} = ((-0.43 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(15.35 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6275 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (15.35 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.6275 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (15.35 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.6275 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 26.139 \text{ kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-0.281 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -0.07025 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.835 \text{ kipft}) + ((-0.281 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.20875 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.20875 \text{ kipft/ft})}{(-0.07025 \text{ kip/ft})}$$

$$E = 2.9715 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.20875 \text{ kipft/ft}) \times (6.75 \text{ ft})) + \left(3 \times (-0.07025 \text{ kip/ft}) \times (6.75 \text{ ft})^2\right)}{(6 \times (0.20875 \text{ kipft/ft})) + (4 \times (-0.07025 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8388 \text{ ft}$$

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

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

$$V_{max} = ((-0.07025 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9715 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8388 \text{ ft})}{(6.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.9715 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8388 \text{ ft})}{(6.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.40648 \text{ kip}$$

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

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

$$M_{max} = ((-0.07025 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[\left(\frac{(2.9715 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8388 \text{ ft})}{2 \times (6.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.9715 \text{ ft})}{(6.75 \text{ ft})} + 3\right) \times \left(\frac{(4.8388 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9715 \text{ ft})}{(6.75 \text{ ft})} + 2\right) \times \left(\frac{(4.8388 \text{ ft})}{2 \times (6.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.203 \text{ kipft}$$

| | | |
|---|---|---|
| | **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* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1809.6 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.098 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1809.6 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -66.126 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-66.126 \text{ in}^2\right), \left(0.0018 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{\left(3.2572 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(3.2572 \text{ in}^2\right)}{\left(3.6816 \text{ in}^2\right)}$$

$$Ratio = 0.88474$$

Status: **PASS**
Ratio: **0.880**

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

Main reinforcement: **12 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1809.6\ \text{in}^2\right) - \left(3.6816\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(3.6816\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2242.3\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.098\ \text{kip})}{(2242.3\ \text{kip})}$$

$$Ratio = 0.0045035$$

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

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

**Parameters:**

$b_w = 48\ \text{in}$ - Effective width,
22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.098\ \text{kip} \rightarrow 10098\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10098\ \text{lbf})}{6 \times (1809.6\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.2\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.2\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.2\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.2\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.21\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 8.0584\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.0584\ \text{kip})}{(111.21\ \text{kip})}$$

$$Ratio = 0.072461$$

Status: **PASS**
Ratio: **0.070**

**Considering z-direction:**

$V_{max} = 0.40648\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.40648\ \text{kip})}{(111.21\ \text{kip})}$$

$$Ratio = 0.0036551$$

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

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

$S_m$ - Section modulus

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

$$S_m = \frac{\pi \times (48\ \text{in})^3}{32}$$

$$S_m = 10857\ \text{in}^3$$

$$S_m = 10857 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 10857.344 in^3$$

$$\phi M_{n,1} = 147.027 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(10857 \text{ in}^3\right)$$

$$\phi M_{n,2} = 1249.7 \text{ kipft}$$

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

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

$$\phi M_n = MIN[(147.03 \text{ kipft}), (1249.7 \text{ kipft})]$$

$$\phi M_n = 147.03 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 26.139 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(26.139 \text{ kipft})}{(147.03 \text{ kipft})}$$

$$Ratio = 0.17779$$

Status: **PASS**
Ratio: **0.180**

**Considering z-direction:**

$M_{max} = 1.203 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.203 \text{ kipft})}{(147.03 \text{ kipft})}$$

$$Ratio = 0.0081821$$

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

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

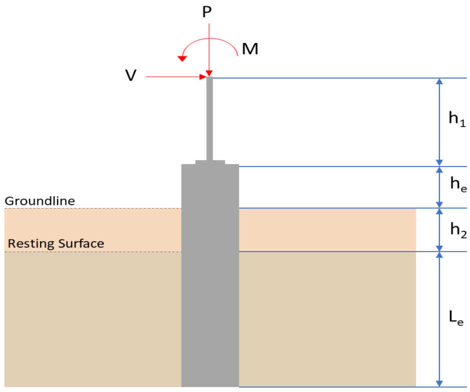
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 48\ \mathrm{in}$ - Pile diameter
$L = 6.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure $(q_a)$ (psf) | Allowable Lateral Pressure $(R)$ (psf/ft) |
|---|---|---|---|
| 1 | Sandy gravel and/or gravel | 3000.000 | 200.000 |

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.174 | 9.193 |
| $V_x$ (kip) | -0.931 | -1.575 |
| $V_z$ (kip) | 0.000 | 0.000 |
| $M_x$ (kipft) | 0.000 | 0.000 |
| $M_z$ (kipft) | 15.060 | 25.803 |

**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,

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

$$H_o = \frac{(-0.931\ \mathrm{kip})}{(48\ \mathrm{in})}$$

$$H_o = -0.23275\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(15.06\ \mathrm{kipft}) + ((-0.931\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(48\ \mathrm{in})}$$

$$M_o = 3.765\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.3084\ \mathrm{ft}$ - Required depth in x-direction,

**Considering z-direction:**

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

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.3084\ \mathrm{ft}), (0\ \mathrm{ft})]$$

$$L_{e,req} = 6.308\ \mathrm{ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.308\ \mathrm{ft})}{(6.75\ \mathrm{ft})}$$

$$Ratio = 0.93452$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

$$A = \pi \times \left(\frac{(48\ \mathrm{in})}{2}\right)^2$$

$$A = 12.566\ \mathrm{ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(6.174\ \mathrm{kip})}{(12.566\ \mathrm{ft}^2)}$$

$$q = 0.49131\ \mathrm{kip/ft}^2$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.49131\ \mathrm{kip/ft}^2)}{(3000\ \mathrm{psf})}$$

$$Ratio = 0.16377$$

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

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.23275\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.765\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.765\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.23275\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (3.765\ \mathrm{kipft/ft})) + (4 \times (-0.23275\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6224\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (3.765\ \mathrm{kipft/ft})) + (3 \times (-0.23275\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (3.765\ \mathrm{kipft/ft})) + (2 \times (-0.23275\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.3395\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (3.765\ \mathrm{kipft/ft})) + ((-0.23275\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 1.2327\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(4.6224\ \mathrm{ft})}{2}$$

$$p_a = 0.46224\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.3395\ \mathrm{kip/ft^2}\right)}{\left(0.46224\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.73446$$

Status: **PASS**
Ratio: **0.730**

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

$$p_s = R\, L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

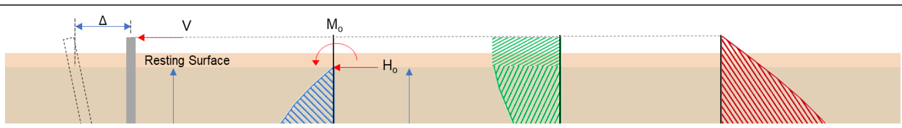
$Ratio$ - Lateral soil capacity

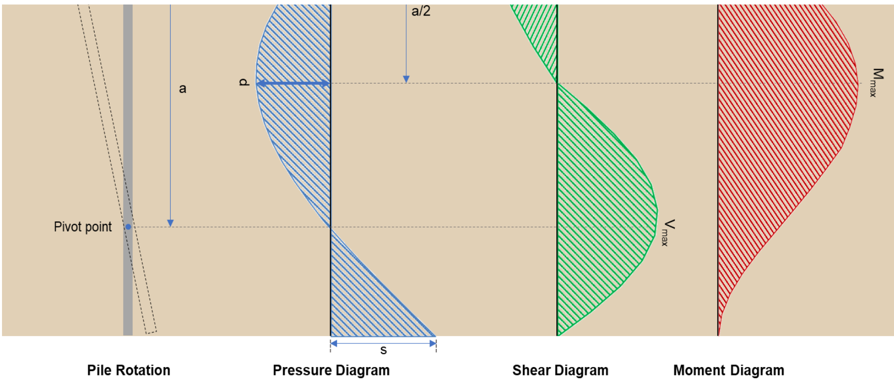
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.2327\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91308$$

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






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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-1.575\ \text{kip})}{(48\ \text{in})}$$

$$H_o = -0.39375\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(25.803\ \text{kipft}) + ((-1.575\ \text{kip}) \times (0\ \text{ft}))}{(48\ \text{in})}$$

$$M_o = 6.4507\ \text{kipft/ft}$$

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

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

$$E = \frac{(6.4507\ \text{kipft/ft})}{(-0.39375\ \text{kip/ft})}$$

$$E = 16.383\ \text{ft}$$

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

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

$$a = \frac{(4 \times (6.4507\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.39375\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (6.4507\ \text{kipft/ft})) + (4 \times (-0.39375\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6212\ \text{ft}$$

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

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

$$V_{max} = ((-0.39375\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.383\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6212\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.383\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6212\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 7.8065\ \text{kip}$$

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

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

$$M_{max} = ((-0.39375\ \text{kip/ft}) \times (48\ \text{in}) \times (6.75\ \text{ft})) \times \left[\left(\frac{(16.383\ \text{ft})}{(6.75\ \text{ft})} + \frac{(4.6212\ \text{ft})}{2 \times (6.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (16.383\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6212\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.383\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6212\ \text{ft})}{2 \times (6.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 25.378 \text{ kipft}$$

**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* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1809.6 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.193 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1809.6 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -66.154 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-66.154 \text{ in}^2\right), \left(0.0018 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{\left(3.2572 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(3.2572 \text{ in}^2\right)}{\left(3.6816 \text{ in}^2\right)}$$

$$Ratio = 0.88474$$

Status: **PASS**
Ratio: **0.880**

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

Main reinforcement: **12 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(1809.6\text{ in}^2\right) - \left(3.6816\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(3.6816\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 2242.3\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.193\text{ kip})}{(2242.3\text{ kip})}$$

$$Ratio = 0.0041$$

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

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

**Parameters:**

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

22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 9.193\text{ kip} \rightarrow 9193\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(9193\text{ lbf})}{6 \times (1809.6\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 120.05\text{ kip}$$

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

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

$$V_c = Min\left[(296.21\text{ kip}), (120.05\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 120.05 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.05 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.11 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 7.8065 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.8065 \text{ kip})}{(111.11 \text{ kip})}$$

$$Ratio = 0.070259$$

Status: **PASS**
Ratio: **0.070**

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

$S_m$ - Section modulus

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

$$S_m = \frac{\pi \times (48 \text{ in})^3}{32}$$

$$S_m = 10857 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 10857.344in^3$$

$$\phi M_{n,1} = 147.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(10857\ \mathrm{in}^3\right)$$

$$\phi M_{n,2} = 1249.7\ \mathrm{kipft}$$

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

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

$$\phi M_n = MIN[(147.03\ \mathrm{kipft}), (1249.7\ \mathrm{kipft})]$$

$$\phi M_n = 147.03\ \mathrm{kipft}$$

**Considering x-direction:**

$M_{max} = 25.378\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(25.378\ \mathrm{kipft})}{(147.03\ \mathrm{kipft})}$$

$$Ratio = 0.17261$$

Status: **PASS**
Ratio: **0.170**

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

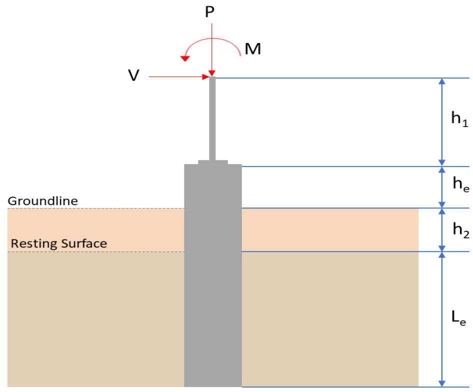
## SkyCiv Foundation Design

Pile Foundation

**Design Information :**

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

### Pile Input




**Geometry**

Pile shape: round
$D = 48 \text{ in}$ - Pile diameter
$L = 6.75 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

**Tabulation of Soil Parameters**

| Layer | Label | Allowable Bearing Pressure $(q_a)$ (psf) | Allowable Lateral Pressure $(R)$ (psf/ft) |
|---|---|---|---|
| 1 | Sandy gravel and/or gravel | 3000.000 | 200.000 |

**Tabulation of Loads**

| Load Component | ASD | LRFD |
|---|---|---|
| $P$ (kip) | 6.765 | 10.098 |
| $V_x$ (kip) | -1.031 | -1.720 |
| $V_z$ (kip) | 0.183 | 0.281 |
| $M_x$ (kipft) | 0.542 | 0.835 |
| $M_z$ (kipft) | 15.482 | 26.403 |

**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,

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

$$H_o = \frac{(-1.031 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -0.25775 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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



SkyCiv

$$M_o = \frac{(15.482 \text{ kipft}) + ((-1.031 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 3.8705 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.2996 \text{ ft}$ - Required depth in x-direction,

**Considering z-direction:**

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.183 \text{ kip})}{(48 \text{ in})}$$

$$H_o = 0.04575 \text{ kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.542 \text{ kipft}) + ((0.183 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.1355 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.7938 \text{ ft}$ - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.2996 \text{ ft}), (2.7938 \text{ ft})]$$

$$L_{e,req} = 6.3 \text{ ft}$$

$L_e$ - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.3 \text{ ft})}{(6.75 \text{ ft})}$$

$$Ratio = 0.93333$$

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

**End-bearing Capacity (ASD)**

$A$ - Pile cros-section area

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

$$A = \pi \times \left(\frac{(48 \text{ in})}{2}\right)^2$$

$$A = 12.566 \text{ ft}^2$$

$q$ - End-bearing pressure

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

$$q = \frac{(6.765 \text{ kip})}{(12.566 \text{ ft}^2)}$$

$$q = 0.53834\ \mathrm{kip/ft^2}$$

**Check bearing capacity ratio:**

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.53834\ \mathrm{kip/ft^2}\right)}{(3000\ \mathrm{psf})}$$

$$Ratio = 0.17945$$

Status: **PASS**
Ratio: **0.180**

*Czerniak*

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.6875$$

Since L/D $\leq$ 10,

Pile is short.

**Considering x-direction:**

$H_o = -0.25775\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.8705\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8705\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (-0.25775\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (3.8705\ \mathrm{kipft/ft})) + (4 \times (-0.25775\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.6297\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (3.8705\ \mathrm{kipft/ft})) + (3 \times (-0.25775\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^{\ 2}}{(6.75\ \mathrm{ft})^2 \times [(3 \times (3.8705\ \mathrm{kipft/ft})) + (2 \times (-0.25775\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.33486\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (3.8705\ \mathrm{kipft/ft})) + ((-0.25775\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 1.2414\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(4.6297\ \mathrm{ft})}{2}$$

$$p_a = 0.46297\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.33486\ \mathrm{kip/ft^2}\right)}{\left(0.46297\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.72328$$

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

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

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2414\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91955$$

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

**Considering z-direction:**

$H_o = 0.04575\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.1355\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
$a$ - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1355\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.1355\ \mathrm{kipft/ft})) + (4 \times (0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8392\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.1355\ \mathrm{kipft/ft})) + (3 \times (0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]^2}{(6.75\ \mathrm{ft})^2 \times [(3 \times (0.1355\ \mathrm{kipft/ft})) + (2 \times (0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}$$

$$p = 0.054437\ \mathrm{kip/ft^2}$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.1355\ \mathrm{kipft/ft})) + ((0.04575\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))]}{(6.75\ \mathrm{ft})^2}$$

$$s = 0.11994\ \mathrm{kip/ft^2}$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(4.8392\ \mathrm{ft})}{2}$$

$$p_a = 0.48392\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.054437\ \mathrm{kip/ft^2}\right)}{\left(0.48392\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.11249$$

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

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

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (6.75\ \mathrm{ft})$$

$$p_s = 1.35\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

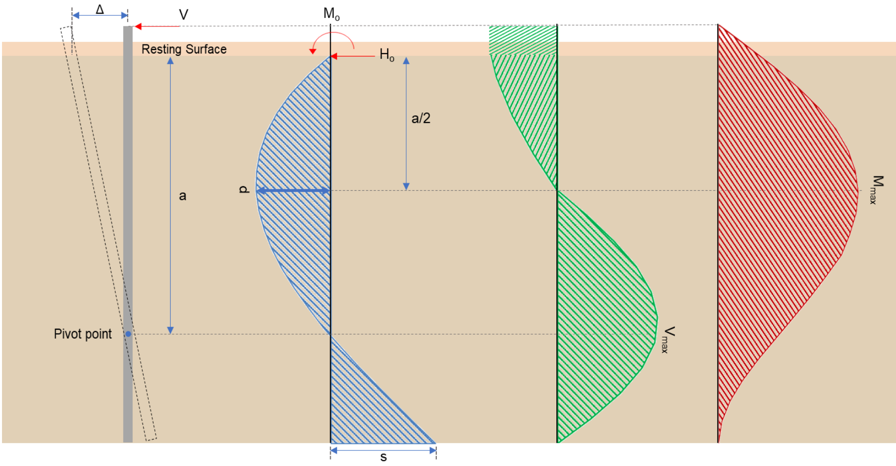
$$Ratio = \frac{s}{}$$

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

$$Ratio = \frac{(0.11994\ \text{kip/ft}^2)}{(1.35\ \text{kip/ft}^2)}$$

$$Ratio = 0.088844$$

Status: **PASS**
Ratio: **0.090**




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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(-1.72\ \text{kip})}{(48\ \text{in})}$$

$$H_o = -0.43\ \text{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(26.403\ \text{kipft}) + ((-1.72\ \text{kip}) \times (0\ \text{ft}))}{(48\ \text{in})}$$

$$M_o = 6.6007\ \text{kipft/ft}$$

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

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

$$E = \frac{(6.6007\ \text{kipft/ft})}{(-0.43\ \text{kip/ft})}$$

$$E = 15.351\ \text{ft}$$

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

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

$$a = \frac{(4 \times (6.6007\ \text{kipft/ft}) \times (6.75\ \text{ft})) + \left(3 \times (-0.43\ \text{kip/ft}) \times (6.75\ \text{ft})^2\right)}{(6 \times (6.6007\ \text{kipft/ft})) + (4 \times (-0.43\ \text{kip/ft}) \times (6.75\ \text{ft}))}$$

$$a = 4.6275\ \text{ft}$$

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

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

$$V_{max} = ((-0.43\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.351\ \text{ft})}{(6.75\ \text{ft})} + 3\right) \times \left(\frac{(4.6275\ \text{ft})}{(6.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (15.351\ \text{ft})}{(6.75\ \text{ft})} + 2\right) \times \left(\frac{(4.6275\ \text{ft})}{(6.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.0587\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.43\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[ \left( \frac{(15.351\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.6275\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right) - \left[ \left( \frac{4 \times (15.351\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3 \right) \times \left( \frac{(4.6275\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (15.351\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2 \right) \times \left( \frac{(4.6275\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right)^4 \right] \right]$$

$$M_{max} = 26.14\ \mathrm{kipft}$$

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

$H_o$ - Lateral force per length of pile,

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

$$H_o = \frac{(0.281\ \mathrm{kip})}{(48\ \mathrm{in})}$$

$$H_o = 0.07025\ \mathrm{kip/ft}$$

$M_o$ - Moment per length of pile,

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

$$M_o = \frac{(0.835\ \mathrm{kipft}) + ((0.281\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(48\ \mathrm{in})}$$

$$M_o = 0.20875\ \mathrm{kipft/ft}$$

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

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

$$E = \frac{(0.20875\ \mathrm{kipft/ft})}{(0.07025\ \mathrm{kip/ft})}$$

$$E = 2.9715\ \mathrm{ft}$$

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

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

$$a = \frac{(4 \times (0.20875\ \mathrm{kipft/ft}) \times (6.75\ \mathrm{ft})) + \left(3 \times (0.07025\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft})^2\right)}{(6 \times (0.20875\ \mathrm{kipft/ft})) + (4 \times (0.07025\ \mathrm{kip/ft}) \times (6.75\ \mathrm{ft}))}$$

$$a = 4.8388\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.07025\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.9715\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3 \right) \times \left( \frac{(4.8388\ \mathrm{ft})}{(6.75\ \mathrm{ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (2.9715\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2 \right) \times \left( \frac{(4.8388\ \mathrm{ft})}{(6.75\ \mathrm{ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.40648\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.07025\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.75\ \mathrm{ft})) \times \left[ \left( \frac{(2.9715\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + \frac{(4.8388\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right) - \left[ \left( \frac{4 \times (2.9715\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 3 \right) \times \left( \frac{(4.8388\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.9715\ \mathrm{ft})}{(6.75\ \mathrm{ft})} + 2 \right) \times \left( \frac{(4.8388\ \mathrm{ft})}{2 \times (6.75\ \mathrm{ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.203 \text{ kipft}$$

**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* $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1809.6 \text{ in}^2$ - Gross area of concrete,

**Longitudinal reinforcement:**

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.098 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1809.6 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -66.126 \text{ in}^2$$

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

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

$$A_{min} = Max\left[\left(-66.126 \text{ in}^2\right), \left(0.0018 \times \left(1809.6 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{\left(3.2572 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(3.2572 \text{ in}^2\right)}{\left(3.6816 \text{ in}^2\right)}$$

$$Ratio = 0.88474$$

Status: **PASS**
Ratio: **0.880**

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

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

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

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

**Ties:**

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

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

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

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

**Summary:**

Main reinforcement: **12 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2 $\phi P_N$ - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(1809.6\ \mathrm{in}^2\right) - \left(3.6816\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(3.6816\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 2242.3\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.098\ \mathrm{kip})}{(2242.3\ \mathrm{kip})}$$

$$Ratio = 0.0045035$$

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

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

**Parameters:**

$b_w = 48\ \mathrm{in}$ - Effective width,
22.5.2.2 $d$ - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 $\lambda_s$ - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$ ,$P = 10.098\ \mathrm{kip} \rightarrow 10098\ \mathrm{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(10098\ \mathrm{lbf})}{6 \times (1809.6\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 120.2\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

$V_c$ - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (120.2\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 120.2\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.2\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.21\ \text{kip}$$

**Considering x-direction:**

$V_{max} = 8.0587\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.0587\ \text{kip})}{(111.21\ \text{kip})}$$

$$Ratio = 0.072463$$

Status: **PASS**
Ratio: **0.070**

**Considering z-direction:**

$V_{max} = 0.40648\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.40648\ \text{kip})}{(111.21\ \text{kip})}$$

$$Ratio = 0.0036551$$

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

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

$S_m$ - Section modulus

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

$$S_m = \frac{\pi \times (48\ \text{in})^3}{32}$$

$$S_m = 10857\ \text{in}^3$$

$$S_m = 10857\ \text{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 10857.344in^3$$

$$\phi M_{n,1} = 147.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(10857\ \text{in}^3\right)$$

$$\phi M_{n,2} = 1249.7\ \text{kipft}$$

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

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

$$\phi M_n = MIN[(147.03\ \text{kipft}), (1249.7\ \text{kipft})]$$

$$\phi M_n = 147.03\ \text{kipft}$$

**Considering x-direction:**

$M_{max} = 26.14\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(26.14\ \text{kipft})}{(147.03\ \text{kipft})}$$

$$Ratio = 0.17779$$

Status: **PASS**
Ratio: **0.180**

**Considering z-direction:**

$M_{max} = 1.203\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.203\ \text{kipft})}{(147.03\ \text{kipft})}$$

$$Ratio = 0.0081821$$

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