

Your Project Calculations



Project Name: KurtJohnsonCarport-JB-RevB

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=KurtJohnsonCarport-JB-RevB&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/7_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=pxTZT10XfLcZhb7BLOzRIX2IEu68b6zrSs3Ugz36ErDVrWjEZ2eRmB7duEqITzM

Array Specification

| | |
|-----------------------------|-------------------------------|
| Product: | Beam |
| Unique ID: | 3P-17-8TOP-XD-45-L-4Hx8W-HGC0 |
| Duty Classification: | XD |
| Module Width: | 40.00 in |
| Module Length: | 71.70in |
| Number of Rows: | 4 |
| Number of Columns: | 8 |
| Total Number of Modules: | 32 |
| Desired Tilt Angle: | 46 |
| Front Edge Clearance: | 7 |
| Total Array Height at Tilt: | 16.65 ft |
| Total Frame Length: | 49.00 ft |
| Frame Weight: | 3009 lbs |
| Array Dimensions N/S: | 13.50 ft |
| Array Dimensions E/W: | 48.47 ft |
| Rail Length: | 162.00 in |
| Rail Spacing: | 2.99 ft |
| Rail Check: | Not Checked |

Support Specifications

| | |
|--------------------------|-----------------|
| Pole Size: | 8in Pipe Sch 40 |
| Pole Length above Grade: | 11.86 ft |
| Number of Poles: | 3 |
| Pole Spacing: | 17 ft |

Foundation Specifications

| | |
|---------------------------------|---|
| Foundation Type: | Square |
| Foundation Dimensions: | 48 x 48 in |
| Foundation Depth (below grade): | Pile 1: 5.50 ft Pile 2: 5.50 ft Pile 3: 5.50 ft |
| Foundation Volume: | 9.778 y ³ |
| Foundation Result: | PASSED |
| Mount Twist: | 0.139406 kip |

Site Info

| | |
|----------------------------|---------------------------------|
| Risk Category: | I |
| Exposure: | B |
| Soil Classification: | sand |
| Site Location: | 31 Main St, Gray, ME 04039, USA |
| Wind Speed: | 103 mph |
| Snow Load: | 70 psf |
| Design Uplift Pressure: | 0.014049 ksf |
| Design Downforce Pressure: | -0.014049 ksf |
| Design Snow Pressure: | 0.018474 ksf |



Design Disclaimer

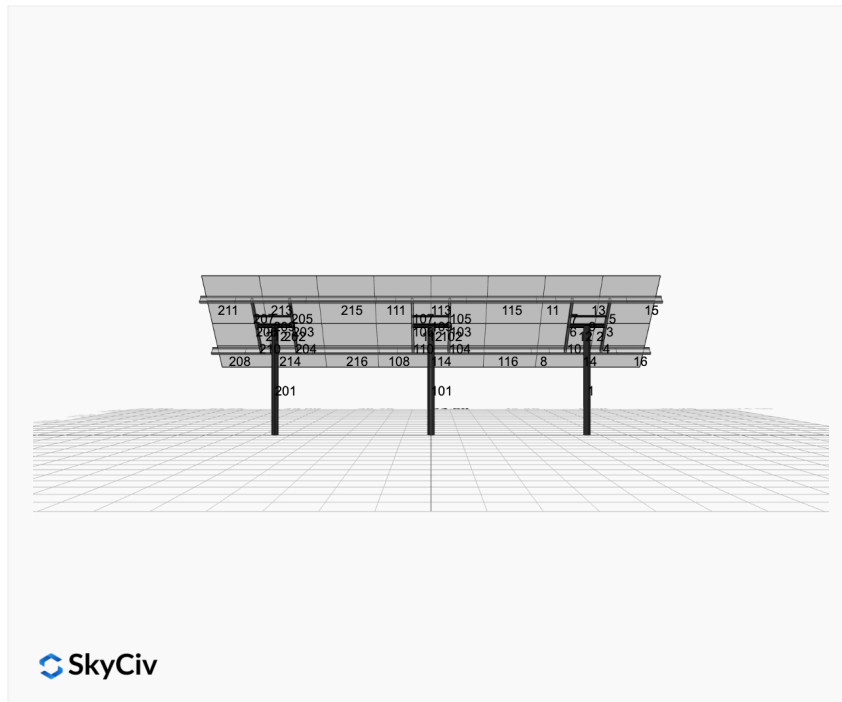
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

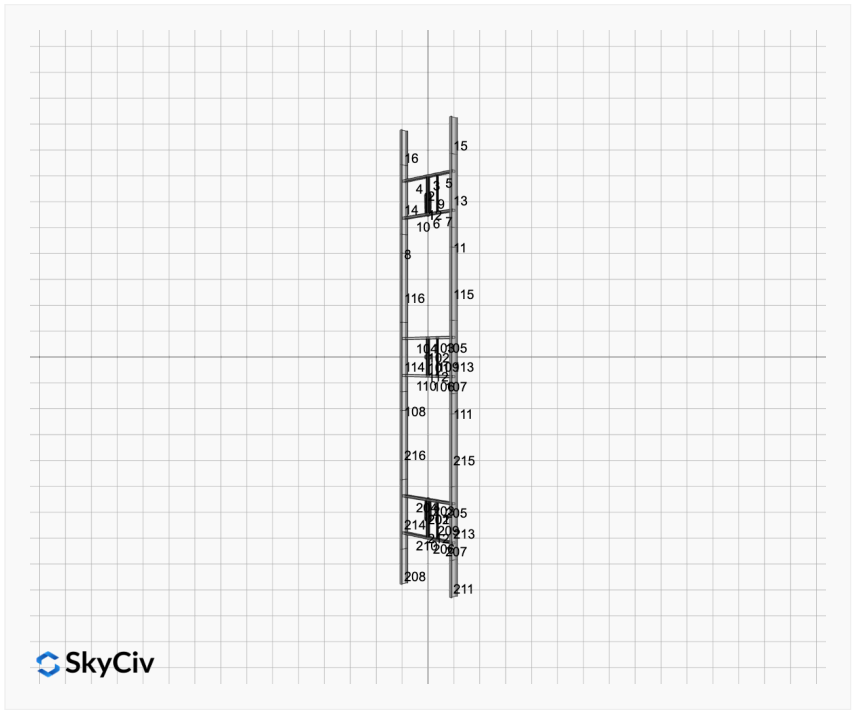
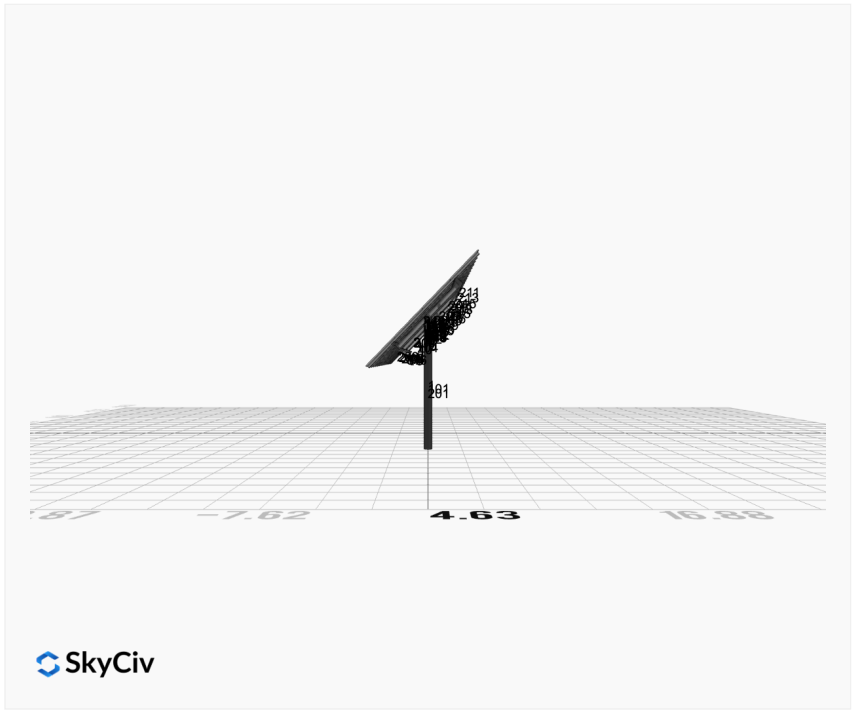
AutoDesigner Input

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  "core_beam_height": 65,
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  "ground_clearance": 7,
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  "exposure_category": "B",
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  "pole_override": "8_40",
  "soil_type": "sand",
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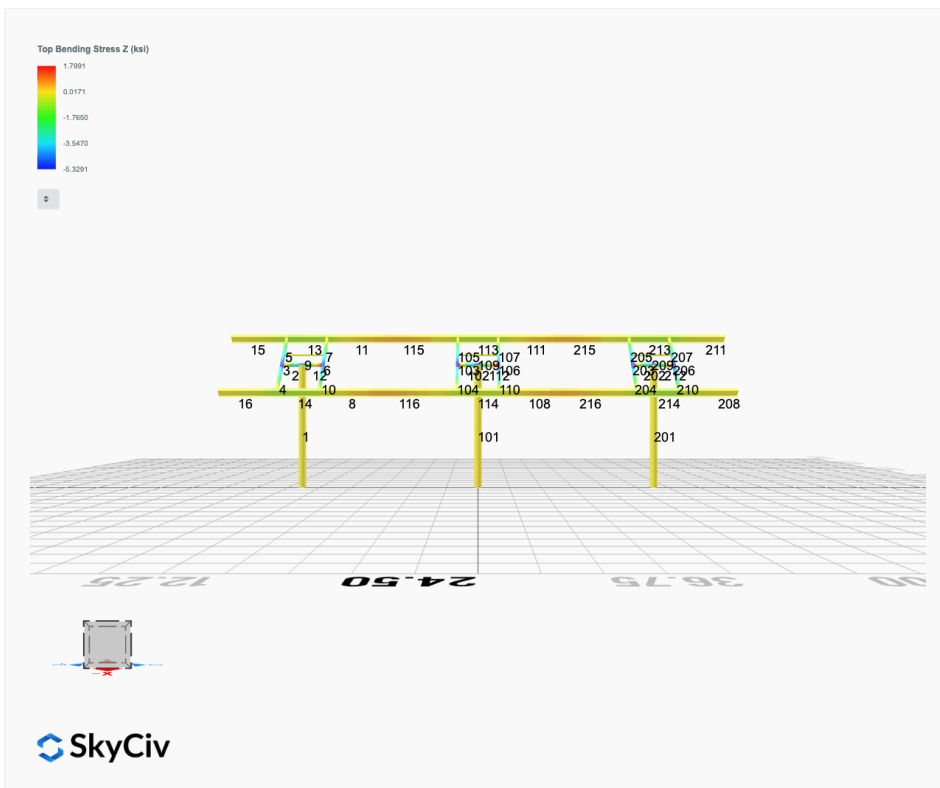
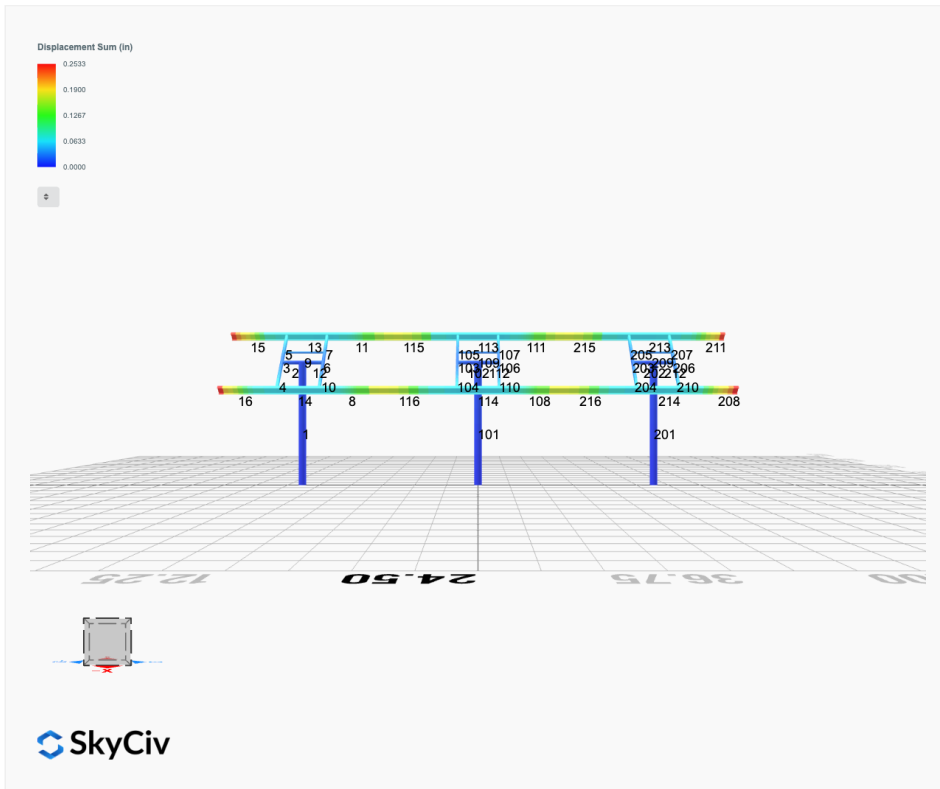
Design Notes:

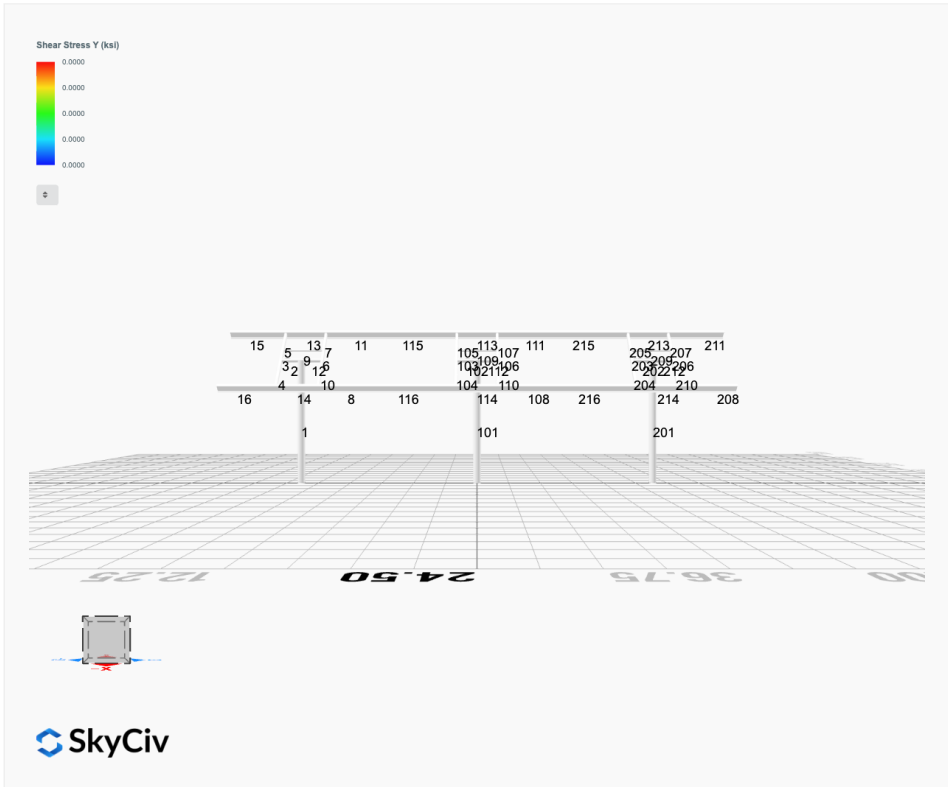
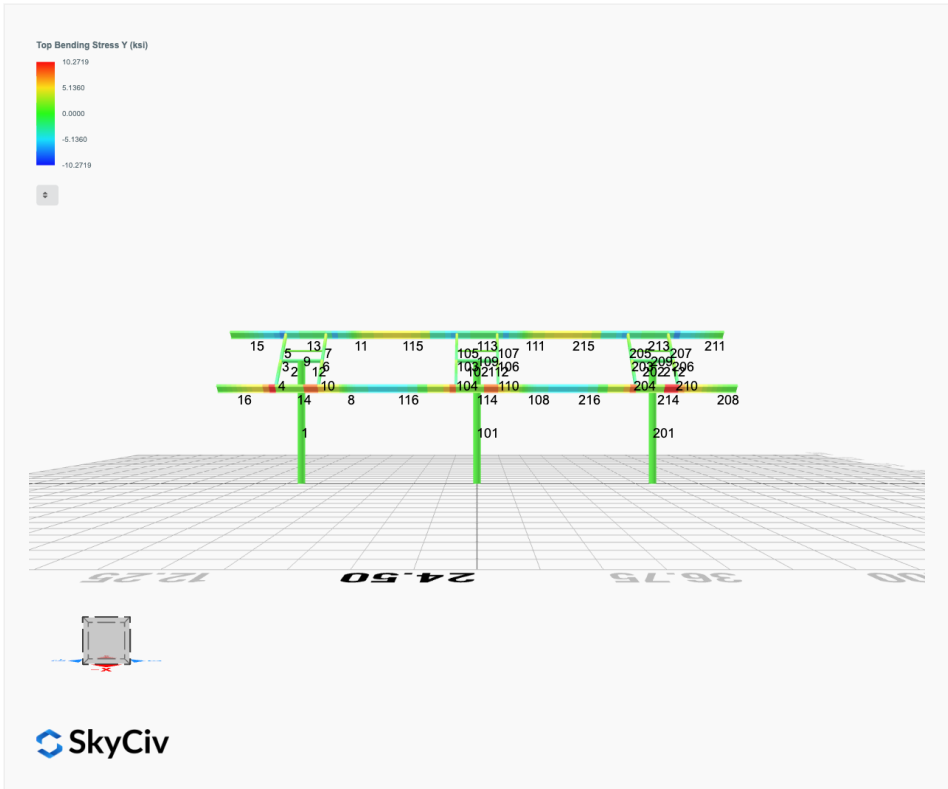
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only

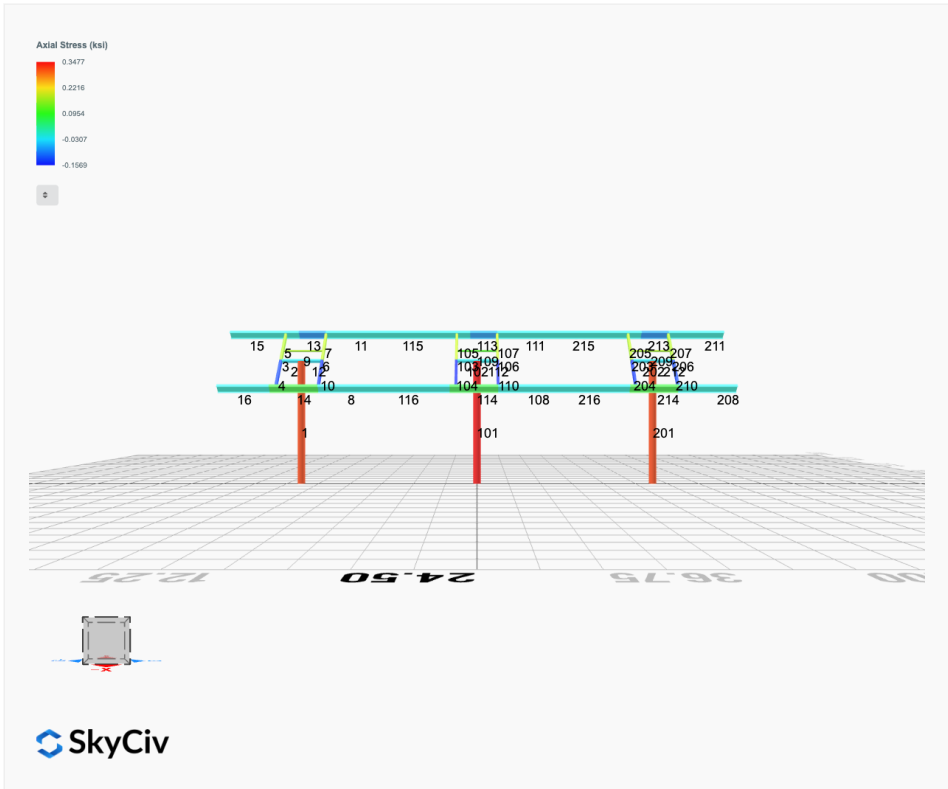




FEM Results (Envelope Worst Case for each member)







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 | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 2. D + L | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 3. D + (S or Lr or R) | -0.0147 | 4.7967 | -0.0062 | -0.0182 | 0.0909 | 0.1779 |
| ULS: 3. D + (S or Lr or R) | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0123 | 4.1007 | -0.0052 | -0.0153 | 0.0759 | 0.1517 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 5b. D + 0.7E | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0123 | 4.1007 | -0.0052 | -0.0153 | 0.0759 | 0.1517 |
| ULS: 8. 0.6D + 0.7E | -0.0030 | 1.2075 | -0.0013 | -0.0039 | 0.0185 | 0.0440 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.3224 | 3.2829 | -0.0045 | -0.0145 | 0.0385 | 15.8082 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.3123 | 0.7423 | 0.0001 | 0.0016 | 0.0229 | -15.4480 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0003 | 5.0534 | -0.0069 | -0.0213 | 0.0817 | 11.9530 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0123 | 4.1007 | -0.0052 | -0.0153 | 0.0759 | 0.1517 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.9757 | 3.1480 | -0.0035 | -0.0092 | 0.0700 | -11.4892 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0123 | 4.1007 | -0.0052 | -0.0153 | 0.0759 | 0.1517 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.9930 | 2.9653 | -0.0039 | -0.0125 | 0.0366 | 11.8745 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.9830 | 1.0599 | -0.0005 | -0.0004 | 0.0249 | -11.5677 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0050 | 2.0126 | -0.0022 | -0.0065 | 0.0308 | 0.0733 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.3204 | 2.4779 | -0.0036 | -0.0119 | 0.0262 | 15.7789 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0030 | 1.2075 | -0.0013 | -0.0039 | 0.0185 | 0.0440 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.3143 | -0.0627 | 0.0010 | 0.0042 | 0.0106 | -15.4773 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0030 | 1.2075 | -0.0013 | -0.0039 | 0.0185 | 0.0440 |

Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 7.9284 |
| Shear X | -2.2067 |
| Shear Z | -0.0110 |
| Moment X | -0.0332 |
| Moment Y (Twist) | 0.1394 |
| Moment Z | 26.7187 |

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 | 5.0534 |
| Shear X | -1.3224 |
| Shear Z | -0.0069 |
| Moment X | -0.0213 |
| Moment Y (Twist) | 0.0909 |
| Moment Z | 15.8082 |

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 | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 2. D + L | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 3. D + (S or Lr or R) | 0.0294 | 5.0018 | -0.0000 | 0.0000 | 0.0000 | -0.2598 |
| ULS: 3. D + (S or Lr or R) | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0246 | 4.2716 | -0.0000 | 0.0000 | 0.0000 | -0.2136 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 5b. D + 0.7E | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---------|---------|---------|--------|--------|----------|
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0246 | 4.2716 | -0.0000 | 0.0000 | 0.0000 | -0.2136 |
| ULS: 8. 0.6D + 0.7E | 0.0060 | 1.2486 | -0.0000 | 0.0000 | 0.0000 | -0.0451 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.3226 | 3.3716 | -0.0000 | 0.0000 | 0.0000 | 15.8140 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.3428 | 0.7903 | -0.0000 | 0.0000 | 0.0000 | -15.7491 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.9749 | 5.2395 | -0.0000 | 0.0000 | 0.0000 | 11.7033 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0246 | 4.2716 | -0.0000 | 0.0000 | 0.0000 | -0.2136 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0241 | 3.3036 | -0.0000 | 0.0000 | 0.0000 | -11.9691 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0246 | 4.2716 | -0.0000 | 0.0000 | 0.0000 | -0.2136 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -0.9894 | 3.0489 | -0.0000 | 0.0000 | 0.0000 | 11.8417 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0096 | 1.1130 | -0.0000 | 0.0000 | 0.0000 | -11.8306 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0100 | 2.0810 | -0.0000 | 0.0000 | 0.0000 | -0.0752 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.3266 | 2.5392 | -0.0000 | 0.0000 | 0.0000 | 15.8441 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0060 | 1.2486 | -0.0000 | 0.0000 | 0.0000 | -0.0451 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.3388 | -0.0421 | -0.0000 | 0.0000 | 0.0000 | -15.7190 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0060 | 1.2486 | -0.0000 | 0.0000 | 0.0000 | -0.0451 |

Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 8.2457 |
| Shear X | -2.2424 |
| Shear Z | -0.0000 |
| Moment X | 0.0001 |
| Moment Y (Twist) | 0.0001 |
| Moment Z | 26.6569 |

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 | 5.2395 |
| Shear X | -1.3428 |
| Shear Z | -0.0000 |
| Moment X | 0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 15.8441 |

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 | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 2. D + L | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 3. D + (S or Lr or R) | -0.0147 | 4.7967 | 0.0062 | 0.0182 | -0.0909 | 0.1779 |
| ULS: 3. D + (S or Lr or R) | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0123 | 4.1007 | 0.0052 | 0.0153 | -0.0759 | 0.1518 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 5b. D + 0.7E | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0123 | 4.1007 | 0.0052 | 0.0153 | -0.0759 | 0.1518 |
| ULS: 8. 0.6D + 0.7E | -0.0030 | 1.2075 | 0.0013 | 0.0039 | -0.0185 | 0.0440 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.3224 | 3.2829 | 0.0045 | 0.0145 | -0.0385 | 15.8082 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.3123 | 0.7423 | -0.0001 | -0.0016 | -0.0229 | -15.4480 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0003 | 5.0534 | 0.0069 | 0.0213 | -0.0817 | 11.9530 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0123 | 4.1007 | 0.0052 | 0.0153 | -0.0759 | 0.1518 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.9757 | 3.1480 | 0.0035 | 0.0092 | -0.0700 | -11.4892 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0123 | 4.1007 | 0.0052 | 0.0153 | -0.0759 | 0.1518 |

| 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 | -0.9930 | 2.9653 | 0.0039 | 0.0125 | -0.0366 | 11.8745 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 0.9830 | 1.0599 | 0.0005 | 0.0004 | -0.0249 | -11.5677 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0050 | 2.0126 | 0.0022 | 0.0065 | -0.0308 | 0.0733 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.3204 | 2.4779 | 0.0036 | 0.0119 | -0.0262 | 15.7789 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0030 | 1.2075 | 0.0013 | 0.0039 | -0.0185 | 0.0440 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.3143 | -0.0627 | -0.0010 | -0.0042 | -0.0106 | -15.4773 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0030 | 1.2075 | 0.0013 | 0.0039 | -0.0185 | 0.0440 |

Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 7.9284 |
| Shear X | -2.2067 |
| Shear Z | 0.0110 |
| Moment X | 0.0333 |
| Moment Y (Twist) | 0.1394 |
| Moment Z | 26.7193 |

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 | 5.0534 |
| Shear X | -1.3224 |
| Shear Z | 0.0069 |
| Moment X | 0.0213 |
| Moment Y (Twist) | 0.0909 |
| Moment Z | 15.8082 |

Project Details

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

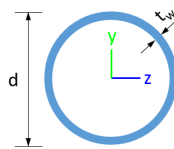


Design Input Information

| Design Factors | | | |
|----------------|----------|----------|----------|
| Φ_t | Φ_c | Φ_b | Φ_v |
| 0.9 | 0.9 | 0.9 | 0.9 |

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

Section Dimensions



| ID | Name | d (in) | t_w (in) | | | | |
|----|------------------|--------|------------|--|--|--|--|
| 3 | 2in Pipe Sch 120 | 2.38 | 0.25 | | | | |
| 6 | 4in Pipe Sch 120 | 4.50 | 0.44 | | | | |
| 9 | 8in Pipe Sch 40 | 8.63 | 0.32 | | | | |



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



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

Section Properties

| ID | Name | A (in ²) | J (in ⁴) | I_{yp} (in ⁴) | I_{zp} (in ⁴) | I_w (in ⁶) | S_{yp} (in ³) | S_{zp} (in ³) |
|----|------------------|----------------------|----------------------|-----------------------------|-----------------------------|--------------------------|-----------------------------|-----------------------------|
| 3 | 2in Pipe Sch 120 | 1.67 | 1.91 | 0.96 | 0.96 | 0.00 | 1.13 | 1.13 |
| 6 | 4in Pipe Sch 120 | 5.58 | 23.29 | 11.64 | 11.64 | 0.00 | 7.24 | 7.24 |
| 9 | 8in Pipe Sch 40 | 8.40 | 144.98 | 72.49 | 72.49 | 0.00 | 22.21 | 22.21 |

| | | | | | | | | |
|-----|----|-----------|-----------|-----------|---|-------------|-------------|---|
| 108 | 20 | 1.33 | 1.33 | 2.0 5 | 1.61,1.62,1.61,1.62,1.62,1.61,1.56,1.62,1.37,1.62,1.55,1.61,1.48,1.61,1.59,1.62,1.69,1.62,1.5 6,1.61,1.34,1.61,1.54,1.61,1.49,1.61 | 3 0 0 | 2 0 0 | 1 |
| 109 | 3 | 2.60 | 2.60 | 4.0 0 | - | 3 0 0 | 2 0 0 | 1 |
| 110 | 17 | 2.44 | 2.44 | 3.7 5 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.68,1.68,1.6 8,1.69,1.55,1.69,1.67,1.69,1.66,1.69 | 3 0 0 | 2 0 0 | 1 |
| 111 | 20 | 1.33 | 1.33 | 2.0 5 | 1.75,1.76,1.75,1.76,1.76,1.75,1.57,1.76,1.23,1.76,1.54,1.75,1.39,1.75,1.66,1.76,2.03,1.76,1.5 8,1.75,1.18,1.75,1.53,1.75,1.42,1.75 | 3 0 0 | 2 0 0 | 1 |
| 112 | 6 | 1.30 | 1.30 | 2.0 0 | - | 3 0 0 | 2 0 0 | 1 |
| 113 | 20 | 4.88 | 4.00 | 7.5 0 | 1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.17,1.05,1.06,1.05,1.08,1.05,1.06,1.05,1.05,1.0 6,1.05,2.66,1.05,1.06,1.05,1.07,1.05 | 3 0 0 | 2 0 0 | 1 |
| 114 | 20 | 4.88 | 4.00 | 7.5 0 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.05,1.06,1.0 6,1.06,1.10,1.06,1.06,1.06,1.06 | 3 0 0 | 2 0 0 | 1 |
| 115 | 20 | 4.84 | 4.84 | 7.4 5 | 1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.14,1.07,1.14,1.12,1.14,1.09,1.14,1.13,1.14,1.16,1.14,1.1 2,1.14,1.06,1.14,1.12,1.14,1.10,1.14 | 3 0 0 | 2 0 0 | 1 |
| 116 | 20 | 4.84 | 4.84 | 7.4 5 | 1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.13,1.09,1.13,1.12,1.13,1.11,1.13,1.12,1.13,1.14,1.13,1.1 2,1.13,1.08,1.13,1.12,1.13,1.11,1.13 | 3 0 0 | 2 0 0 | 1 |
| 201 | 9 | 24.9 0 | 24.9 0 | 11. 86 | - | 3 0 0 | 2 0 0 | 1 |
| 202 | 6 | 1.30 | 1.30 | 2.0 0 | - | 3 0 0 | 2 0 0 | 1 |
| 203 | 17 | 0.92 | 0.92 | 1.4 2 | 1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.1 8,1.19,1.12,1.19,1.18,1.19,1.17,1.19 | 3 0 0 | 2 0 0 | 1 |
| 204 | 17 | 2.44 | 2.44 | 3.7 5 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.68,1.68,1.6 8,1.69,1.56,1.69,1.67,1.69,1.65,1.69 | 3 0 0 | 2 0 0 | 1 |
| 205 | 17 | 1.52 | 1.52 | 2.3 3 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.6 7,1.68,1.61,1.68,1.67,1.68,1.66,1.68 | 3 0 0 | 2 0 0 | 1 |
| 206 | 17 | 0.92 | 0.92 | 1.4 2 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.1 8,1.19,1.12,1.19,1.18,1.19,1.17,1.19 | 3 0 0 | 2 0 0 | 1 |
| 207 | 17 | 1.52 | 1.52 | 2.3 3 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.6 7,1.68,1.60,1.68,1.67,1.68,1.66,1.68 | 3 0 0 | 2 0 0 | 1 |
| 208 | 20 | 7.88 | 7.88 | 3.7 5 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33,2.33 | 3 0 0 | 2 0 0 | 1 |
| 209 | 3 | 2.60 | 2.60 | 4.0 0 | - | 3 0 0 | 2 0 0 | 1 |
| 210 | 17 | 2.44 | 2.44 | 3.7 5 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.68,1.68,1.6 8,1.69,1.55,1.69,1.67,1.69,1.65,1.69 | 3 0 0 | 2 0 0 | 1 |
| 211 | 20 | 7.88 | 7.88 | 3.7 5 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33,2.33 | 3 0 0 | 2 0 0 | 1 |
| 212 | 6 | 2.00 | 1.30 | 2.0 0 | - | 3 0 0 | 2 0 0 | 1 |
| 213 | 20 | 4.88 | 4.00 | 7.5 0 | 1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.1 1,1.11,1.11,1.11,1.11,1.11,1.11,1.11 | 3 0 0 | 2 0 0 | 1 |
| 214 | 20 | 4.88 | 4.00 | 7.5 0 | 1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.1 1,1.11,1.11,1.11,1.11,1.11,1.11,1.11 | 3 0 0 | 2 0 0 | 1 |
| 215 | 20 | 4.84 | 4.84 | 7.4 5 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.19,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.1 6,1.16,1.20,1.16,1.16,1.16,1.16 | 3 0 0 | 2 0 0 | 1 |
| 216 | 20 | 4.84 | 4.84 | 7.4 5 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.1 6,1.16,1.16,1.16,1.16,1.16,1.16,1.16 | 3 0 0 | 2 0 0 | 1 |

Member Design Capacity

Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|-----------|--------------------|--------------------|------------------------|------------------------|-----------------------|-----------------------|
| 1 | 377.97 | 177.44 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 251.01 | 246.00 | 27.16 | 27.16 | 75.30 | 75.30 |
| 3 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 4 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 5 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 6 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 7 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 8 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 9 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 10 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 11 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 12 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 13 | 159.30 | 116.35 | 33.92 | 6.46 | 56.26 | 44.91 |
| 14 | 159.30 | 116.35 | 33.92 | 6.46 | 56.26 | 44.91 |
| 15 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 16 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 101 | 377.97 | 177.44 | 83.29 | 83.29 | 113.39 | 113.39 |
| 102 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 103 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 104 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 105 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 106 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 107 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 108 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 109 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 110 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 111 | 159.30 | 142.47 | 46.90 | 6.46 | 56.26 | 44.91 |
| 112 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 113 | 159.30 | 116.35 | 32.09 | 6.46 | 56.26 | 44.91 |
| 114 | 159.30 | 116.35 | 32.09 | 6.46 | 56.26 | 44.91 |
| 115 | 159.30 | 104.63 | 32.58 | 6.46 | 56.26 | 44.91 |
| 116 | 159.30 | 104.63 | 33.20 | 6.46 | 56.26 | 44.91 |
| 201 | 377.97 | 177.44 | 83.29 | 83.29 | 113.39 | 113.39 |
| 202 | 251.01 | 248.88 | 27.16 | 27.16 | 75.30 | 75.30 |
| 203 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 204 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 205 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 206 | 151.65 | 150.70 | 20.17 | 14.14 | 54.12 | 28.95 |
| 207 | 151.65 | 149.10 | 20.17 | 14.14 | 54.12 | 28.95 |
| 208 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 209 | 75.10 | 66.32 | 4.25 | 4.25 | 22.53 | 22.53 |
| 210 | 151.65 | 145.15 | 20.17 | 14.14 | 54.12 | 28.95 |
| 211 | 159.30 | 55.15 | 46.90 | 6.46 | 56.26 | 44.91 |
| 212 | 251.01 | 246.00 | 27.16 | 27.16 | 75.30 | 75.30 |
| 213 | 159.30 | 116.35 | 33.92 | 6.46 | 56.26 | 44.91 |
| 214 | 159.30 | 116.35 | 33.92 | 6.46 | 56.26 | 44.91 |
| 215 | 159.30 | 104.63 | 35.66 | 6.46 | 56.26 | 44.91 |
| 216 | 159.30 | 104.63 | 35.66 | 6.46 | 56.26 | 44.91 |

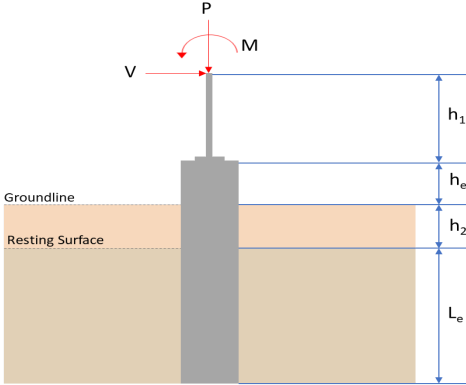
Design Ratio

| Member ID | P | M _z | M _y | V _y | V _z | (P,M _z ,M _y) | Worst LC | KL/r | φ | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|--------------|--------------|--------|
| 1 | 0.045 | 0.321 | 0.001 | 0.019 | 0.000 | 0.338 | #13 | 0.508 | Not Required | Pass |
| 2 | 0.002 | 0.210 | 0.089 | 0.050 | 0.015 | 0.281 | #21 | 0.055 | Not Required | Pass |
| 3 | 0.007 | 0.278 | 0.050 | 0.028 | 0.010 | 0.332 | #21 | 0.046 | Not Required | Pass |
| 4 | 0.007 | 0.276 | 0.108 | 0.028 | 0.024 | 0.352 | #21 | 0.082 | Not Required | Pass |
| 5 | 0.007 | 0.172 | 0.111 | 0.027 | 0.028 | 0.196 | #21 | 0.076 | Not Required | Pass |
| 6 | 0.008 | 0.272 | 0.054 | 0.027 | 0.011 | 0.330 | #21 | 0.046 | Not Required | Pass |
| 7 | 0.008 | 0.168 | 0.108 | 0.027 | 0.028 | 0.198 | #21 | 0.076 | Not Required | Pass |
| 8 | 0.000 | 0.022 | 0.084 | 0.016 | 0.015 | 0.106 | #21 | 0.068 | Not Required | Pass |
| 9 | 0.007 | 0.020 | 0.027 | 0.001 | 0.000 | 0.047 | #21 | 0.206 | Not Required | Pass |
| 10 | 0.008 | 0.272 | 0.106 | 0.027 | 0.024 | 0.355 | #21 | 0.082 | Not Required | Pass |
| 11 | 0.000 | 0.022 | 0.083 | 0.016 | 0.015 | 0.105 | #21 | 0.102 | Not Required | Pass |
| 12 | 0.002 | 0.206 | 0.086 | 0.050 | 0.015 | 0.272 | #21 | 0.036 | Not Required | Pass |
| 13 | 0.005 | 0.088 | 0.322 | 0.021 | 0.020 | 0.402 | #21 | 0.306 | Not Required | Pass |
| 14 | 0.006 | 0.090 | 0.322 | 0.021 | 0.020 | 0.402 | #21 | 0.204 | Not Required | Pass |
| 15 | 0.000 | 0.027 | 0.150 | 0.012 | 0.011 | 0.176 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.027 | 0.150 | 0.012 | 0.011 | 0.176 | #21 | Not Required | Not Required | Pass |
| 101 | 0.046 | 0.320 | 0.000 | 0.020 | 0.000 | 0.337 | #13 | 0.508 | Not Required | Pass |
| 102 | 0.001 | 0.216 | 0.087 | 0.052 | 0.015 | 0.283 | #21 | 0.036 | Not Required | Pass |
| 103 | 0.008 | 0.285 | 0.059 | 0.029 | 0.014 | 0.348 | #21 | 0.046 | Not Required | Pass |
| 104 | 0.008 | 0.281 | 0.100 | 0.028 | 0.023 | 0.360 | #21 | 0.082 | Not Required | Pass |
| 105 | 0.008 | 0.176 | 0.102 | 0.028 | 0.025 | 0.200 | #21 | 0.076 | Not Required | Pass |
| 106 | 0.008 | 0.285 | 0.059 | 0.029 | 0.014 | 0.348 | #21 | 0.046 | Not Required | Pass |
| 107 | 0.008 | 0.176 | 0.102 | 0.028 | 0.025 | 0.200 | #21 | 0.076 | Not Required | Pass |
| 108 | 0.000 | 0.026 | 0.086 | 0.015 | 0.014 | 0.111 | #21 | 0.068 | Not Required | Pass |
| 109 | 0.005 | 0.016 | 0.025 | 0.001 | 0.000 | 0.043 | #21 | 0.206 | Not Required | Pass |
| 110 | 0.008 | 0.281 | 0.100 | 0.028 | 0.023 | 0.360 | #21 | 0.082 | Not Required | Pass |
| 111 | 0.000 | 0.025 | 0.085 | 0.015 | 0.014 | 0.109 | #21 | 0.102 | Not Required | Pass |
| 112 | 0.001 | 0.216 | 0.087 | 0.052 | 0.015 | 0.283 | #21 | 0.036 | Not Required | Pass |
| 113 | 0.005 | 0.069 | 0.287 | 0.020 | 0.020 | 0.345 | #21 | 0.306 | Not Required | Pass |
| 114 | 0.005 | 0.066 | 0.286 | 0.020 | 0.020 | 0.341 | #21 | 0.204 | Not Required | Pass |
| 115 | 0.000 | 0.050 | 0.161 | 0.015 | 0.014 | 0.211 | #21 | 0.370 | Not Required | Pass |
| 116 | 0.000 | 0.052 | 0.162 | 0.015 | 0.014 | 0.214 | #21 | 0.247 | Not Required | Pass |
| 201 | 0.045 | 0.321 | 0.001 | 0.019 | 0.000 | 0.338 | #13 | 0.508 | Not Required | Pass |
| 202 | 0.002 | 0.206 | 0.086 | 0.050 | 0.015 | 0.272 | #21 | 0.036 | Not Required | Pass |
| 203 | 0.008 | 0.272 | 0.054 | 0.027 | 0.011 | 0.330 | #21 | 0.046 | Not Required | Pass |
| 204 | 0.008 | 0.272 | 0.106 | 0.027 | 0.024 | 0.355 | #21 | 0.082 | Not Required | Pass |
| 205 | 0.008 | 0.168 | 0.108 | 0.027 | 0.028 | 0.198 | #21 | 0.076 | Not Required | Pass |
| 206 | 0.007 | 0.278 | 0.050 | 0.028 | 0.010 | 0.332 | #21 | 0.046 | Not Required | Pass |
| 207 | 0.007 | 0.172 | 0.111 | 0.027 | 0.028 | 0.196 | #21 | 0.076 | Not Required | Pass |
| 208 | 0.000 | 0.027 | 0.150 | 0.012 | 0.011 | 0.176 | #21 | Not Required | Not Required | Pass |
| 209 | 0.007 | 0.020 | 0.027 | 0.001 | 0.000 | 0.047 | #21 | 0.206 | Not Required | Pass |
| 210 | 0.007 | 0.276 | 0.108 | 0.028 | 0.024 | 0.352 | #21 | 0.082 | Not Required | Pass |
| 211 | 0.000 | 0.027 | 0.150 | 0.012 | 0.011 | 0.176 | #21 | Not Required | Not Required | Pass |
| 212 | 0.002 | 0.210 | 0.089 | 0.050 | 0.015 | 0.281 | #21 | 0.055 | Not Required | Pass |
| 213 | 0.005 | 0.088 | 0.322 | 0.021 | 0.020 | 0.402 | #21 | 0.204 | Not Required | Pass |
| 214 | 0.006 | 0.090 | 0.322 | 0.021 | 0.020 | 0.402 | #21 | 0.204 | Not Required | Pass |
| 215 | 0.000 | 0.049 | 0.161 | 0.016 | 0.015 | 0.210 | #21 | 0.370 | Not Required | Pass |
| 216 | 0.000 | 0.050 | 0.162 | 0.016 | 0.015 | 0.212 | #21 | 0.247 | Not Required | Pass |

Definitions

Φ_t Safety factor for tensile

| | |
|---------------------|---|
| Φ_c | Safety factor for compression |
| Φ_b | Safety factor for flexure |
| Φ_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/compression) |
| 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 | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|---|--|---|--|---|---|---|----------|---------|----------------|-----|------|-----------|-------|-------|-------------|--------|--------|-------------|--------|--------|---------------|--------|--------|---------------|--------|--------|--|
| | <p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Pile Input</p>  <p>Geometry Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 5.5$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.053</td> <td>7.928</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.322</td> <td>-2.207</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.007</td> <td>-0.011</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.021</td> <td>-0.033</td> </tr> <tr> <td>M_z (kipft)</td> <td>15.808</td> <td>26.719</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p> | Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 5.053 | 7.928 | V_x (kip) | -1.322 | -2.207 | V_z (kip) | -0.007 | -0.011 | M_x (kipft) | -0.021 | -0.033 | M_z (kipft) | 15.808 | 26.719 | |
| Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 5.053 | 7.928 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_x (kip) | -1.322 | -2.207 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_z (kip) | -0.007 | -0.011 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_x (kipft) | -0.021 | -0.033 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_z (kipft) | 15.808 | 26.719 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.322 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.21051 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ | | | | | | | | | | | | | | | | | | | | | | | | | | | |

$$M_o = \frac{(15.808 \text{ kipft}) + ((-1.322 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.5172 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.1472 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.007 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0011146 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021 \text{ kipft}) + ((-0.007 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0033439 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.60966 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.1472 \text{ ft}), (0.60966 \text{ ft})]$$

$$L_{e,req} = 5.147 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.147 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.93582$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.053 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.31581 \text{ kip/ft}^2$$

$$q = 0.31581 \text{ kip/ft}$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.31581 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.15791$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.21051 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 2.5172 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5172 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.5172 \text{ kipft/ft})) + (4 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7742 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (2.5172 \text{ kipft/ft})) + (3 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 [(3 \times (2.5172 \text{ kipft/ft})) + (2 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.20598 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 [(2 \times (2.5172 \text{ kipft/ft})) + ((-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.76891 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7742 \text{ ft})}{2}$$

$$p_a = 0.28307 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20598 \text{ kip/ft}^2)}{(0.28307 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.72766$$

p_a - Allowable lateral soil pressure at depth L_e ,

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

| | | |
|--|--|--|
| | $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.76891 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.93201$ | Status: PASS Ratio: 0.930 |
| | <p>Considering z-direction:</p> <p>$H_o = -0.0011146 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.0033439 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.0033439 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.0033439 \text{ kipft/ft})) + (4 \times (-0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9188 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.0033439 \text{ kipft/ft})) + (3 \times (-0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.0033439 \text{ kipft/ft})) + (2 \times (-0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = -0.00027981 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.0033439 \text{ kipft/ft})) + ((-0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.00011054 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9188 \text{ ft})}{2}$ $p_a = 0.29391 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.00027981 \text{ kip/ft}^2)}{(0.29391 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.00095205$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ | Status: PASS Ratio: 0.000 |

$$\text{Ratio} = \frac{(0.00011054 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.00013399$$

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



Shear force and Bending moment (x-direction, LRF)

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.207 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35143 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.719 \text{ kipft}) + ((-2.207 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2546 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2546 \text{ kipft/ft})}{(-0.35143 \text{ kip/ft})}$$

$$E = 12.106 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2546 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.35143 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.2546 \text{ kipft/ft})) + (4 \times (-0.35143 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7732 \text{ ft}$$

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

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

$$V_{max} = ((-0.35143 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7732 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7732 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.4043 \text{ kip}$$

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

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

$$M_{max} = ((-0.35143 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(12.106 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 16.908 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.011 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0017516 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.033 \text{ kipft}) + ((-0.011 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0052548 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0052548 \text{ kipft/ft})}{(-0.0017516 \text{ kip/ft})}$$

$$E = 3 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0052548 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.0017516 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.0052548 \text{ kipft/ft})) + (4 \times (-0.0017516 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9188 \text{ ft}$$

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

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

$$V_{max} = ((-0.0017516 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9188 \text{ ft})}{(5.5 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9188 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.011424 \text{ kip}$$

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

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

$$M_{max} = ((-0.0017516 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.027976 \text{ kipft}$$

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

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.928 \text{ kip})}{(0.65)(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.333 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.333 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Ties: #3(0.375 in) - 10 in

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2

ϕP_N - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(7.928 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0029635$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.928 \text{ kip} \rightarrow 7928 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7928 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.54 \text{ kip}$$

22.5.5.1.2

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

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

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

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

V_c - Governing shear strength of concrete

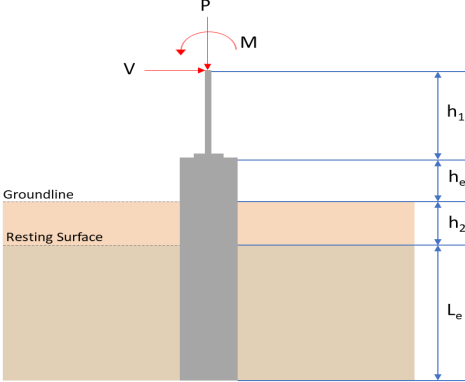
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.54 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.54 \text{ kip}$$

| | | |
|-----------------|--|---|
| <p>22.5.1.2</p> | <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((119.54 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.78 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 6.4043 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(6.4043 \text{ kip})}{(110.78 \text{ kip})}$ $\text{Ratio} = 0.057809$ <p>Considering z-direction:</p> <p>$V_{max} = 0.011424 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.011424 \text{ kip})}{(110.78 \text{ kip})}$ $\text{Ratio} = 0.00010312$ | <p>Status: PASS Ratio: 0.060</p> <p>Status: PASS Ratio: 0.000</p> |
| | <p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ | |

| | | |
|------------------|--|---|
| <p>14.5.2.1b</p> | <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p>Considering x-direction: $M_{max} = 16.908 \text{kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(16.908 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.06774$ | <p>Status: PASS Ratio: 0.070</p> |
| | <p>Considering z-direction: $M_{max} = 0.027976 \text{kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.027976 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.00011208$ | <p>Status: PASS Ratio: 0.000</p> |

| REFERENCES | CALCULATIONS | RESULTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|---|--|---|--|---|---|---|----------|---------|----------------|-----|------|-----------|-------|-------|-------------|--------|--------|-------------|-------|-------|---------------|-------|-------|---------------|--------|--------|--|
| | <p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Pile Input</p>  <p>Geometry Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 5.5$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.240</td> <td>8.246</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.343</td> <td>-2.242</td> </tr> <tr> <td>V_z (kip)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td>M_z (kipft)</td> <td>15.844</td> <td>26.657</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p> | Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 5.240 | 8.246 | V_x (kip) | -1.343 | -2.242 | V_z (kip) | 0.000 | 0.000 | M_x (kipft) | 0.000 | 0.000 | M_z (kipft) | 15.844 | 26.657 | |
| Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 5.240 | 8.246 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_x (kip) | -1.343 | -2.242 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_z (kip) | 0.000 | 0.000 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_x (kipft) | 0.000 | 0.000 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_z (kipft) | 15.844 | 26.657 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.343 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.21385 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ | | | | | | | | | | | | | | | | | | | | | | | | | | | |

$$M_o = \frac{(15.844 \text{ kipft}) + ((-1.343 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.5229 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$$L_{e,x} = 5.1409 \text{ ft} - \text{Required depth in x-direction,}$$

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.1409 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.141 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.141 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.93473$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.24 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.3275 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

$$\text{Ratio} = \frac{q}{q_o}$$

$$\text{Ratio} = \frac{(0.3275 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.16375$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.21385$ kip/ft - Lateral force per length of pile,

$M_o = 2.5229$ kipft/ft - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5229 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.21385 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.5229 \text{ kipft/ft})) + (4 \times (-0.21385 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7753 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.5229 \text{ kipft/ft})) + (3 \times (-0.21385 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.5229 \text{ kipft/ft})) + (2 \times (-0.21385 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.20473 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (2.5229 \text{ kipft/ft})) + ((-0.21385 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.76754 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7753 \text{ ft})}{2}$$

$$p_a = 0.28315 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20473 \text{ kip/ft}^2)}{(0.28315 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.72305$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

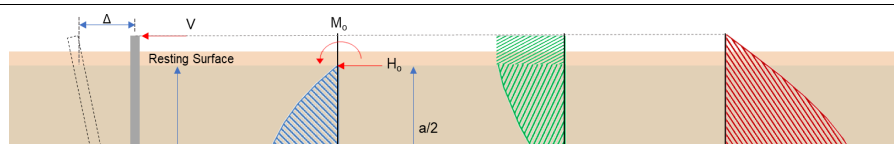
$$\text{Ratio} = \frac{s}{p_s}$$

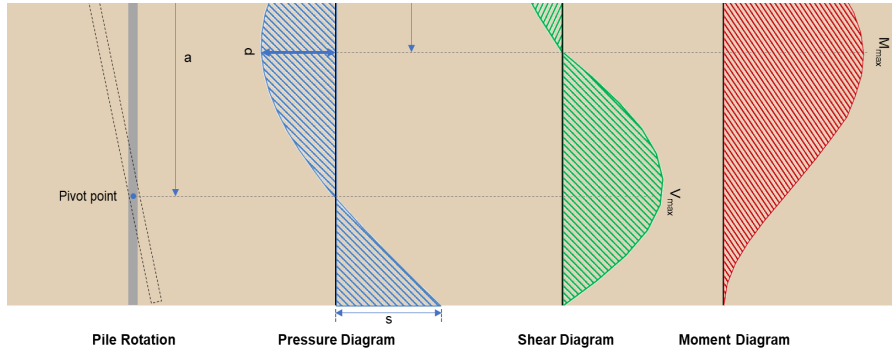
$$\text{Ratio} = \frac{(0.76754 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.93035$$

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

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.242 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35701 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.657 \text{ kipft}) + ((-2.242 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2447 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2447 \text{ kipft/ft})}{(-0.35701 \text{ kip/ft})}$$

$$E = 11.89 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2447 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.35701 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.2447 \text{ kipft/ft})) + (4 \times (-0.35701 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7747 \text{ ft}$$

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

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

$$V_{max} = ((-0.35701 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.89 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7747 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (11.89 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7747 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.4062 \text{ kip}$$

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

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

$$M_{max} = ((-0.35701 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(11.89 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7747 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.89 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7747 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.89 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7747 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 16.902 \text{ kipft}$$

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

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.246 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.322 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.322 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(8.246 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0030824$$

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 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.246 \text{ kip} \rightarrow 8246 \text{ lbf}$,22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8246 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.58 \text{ kip}$$

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)

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

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

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

 V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.58 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.58 \text{ kip}$$

| | | |
|------------------|--|---|
| <p>22.5.1.2</p> | <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((119.58 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.81 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 6.4062 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(6.4062 \text{ kip})}{(110.81 \text{ kip})}$ $\text{Ratio} = 0.057812$ | <p>Status: PASS Ratio: 0.060</p> |
| <p>14.5.2.1b</p> | <p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kip ft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = 0.85 f'_c S_m$ | |

$\phi M_{n,2} = \phi M_{n,1}$

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

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

Therefore,
 ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

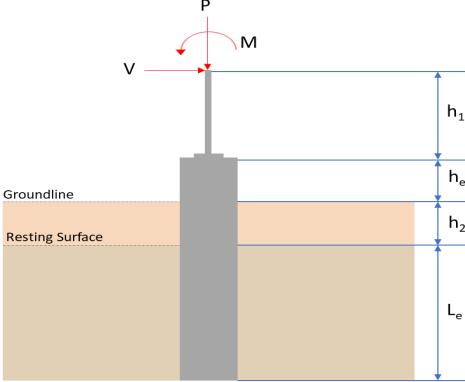
$M_{max} = 16.902 \text{ kipft}$ - Maximum moment in the x-direction,
Ratio - Capacity

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

$$\text{Ratio} = \frac{(16.902 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.067716$$

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

| REFERENCES | CALCULATIONS | RESULTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|---|--|---|--|---|---|---|----------|---------|----------------|-----|------|-----------|-------|-------|-------------|--------|--------|-------------|-------|-------|---------------|-------|-------|---------------|--------|--------|--|
| | <p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Pile Input</p>  <p>Geometry Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 5.5$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.053</td> <td>7.928</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.322</td> <td>-2.207</td> </tr> <tr> <td>V_z (kip)</td> <td>0.007</td> <td>0.011</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.021</td> <td>0.033</td> </tr> <tr> <td>M_z (kipft)</td> <td>15.808</td> <td>26.719</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p> | Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | Load Component | ASD | LRFD | P (kip) | 5.053 | 7.928 | V_x (kip) | -1.322 | -2.207 | V_z (kip) | 0.007 | 0.011 | M_x (kipft) | 0.021 | 0.033 | M_z (kipft) | 15.808 | 26.719 | |
| Layer | Label | Allowable Bearing Pressure (q_a) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sand, silty sand, clayey sand, silty gravel & clayey gravel | 2000.000 | 150.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 5.053 | 7.928 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_x (kip) | -1.322 | -2.207 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V_z (kip) | 0.007 | 0.011 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_x (kipft) | 0.021 | 0.033 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M_z (kipft) | 15.808 | 26.719 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.322 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.21051 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ | | | | | | | | | | | | | | | | | | | | | | | | | | | |

$$M_o = \frac{(15.808 \text{ kipft}) + ((-1.322 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.5172 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.1472 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.007 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0011146 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021 \text{ kipft}) + ((0.007 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0033439 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.67852 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.1472 \text{ ft}), (0.67852 \text{ ft})]$$

$$L_{e,req} = 5.147 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.147 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.93582$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.053 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.31581 \text{ kip/ft}^2$$

$$q = 0.31581 \text{ kip/ft}$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.31581 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.15791$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.21051 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 2.5172 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5172 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.5172 \text{ kipft/ft})) + (4 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7742 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (2.5172 \text{ kipft/ft})) + (3 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 [(3 \times (2.5172 \text{ kipft/ft})) + (2 \times (-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.20598 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 [(2 \times (2.5172 \text{ kipft/ft})) + ((-0.21051 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.76891 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7742 \text{ ft})}{2}$$

$$p_a = 0.28307 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20598 \text{ kip/ft}^2)}{(0.28307 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.72766$$

p_a - Allowable lateral soil pressure at depth L_e ,

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.76891 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.93201$$

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

Considering z-direction:

$H_o = 0.0011146 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0033439 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0033439 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.0033439 \text{ kipft/ft})) + (4 \times (0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9188 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0033439 \text{ kipft/ft})) + (3 \times (0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.0033439 \text{ kipft/ft})) + (2 \times (0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.0011224 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0033439 \text{ kipft/ft})) + ((0.0011146 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.0025425 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9188 \text{ ft})}{2}$$

$$p_a = 0.29391 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0011224 \text{ kip/ft}^2)}{(0.29391 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.0038188$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

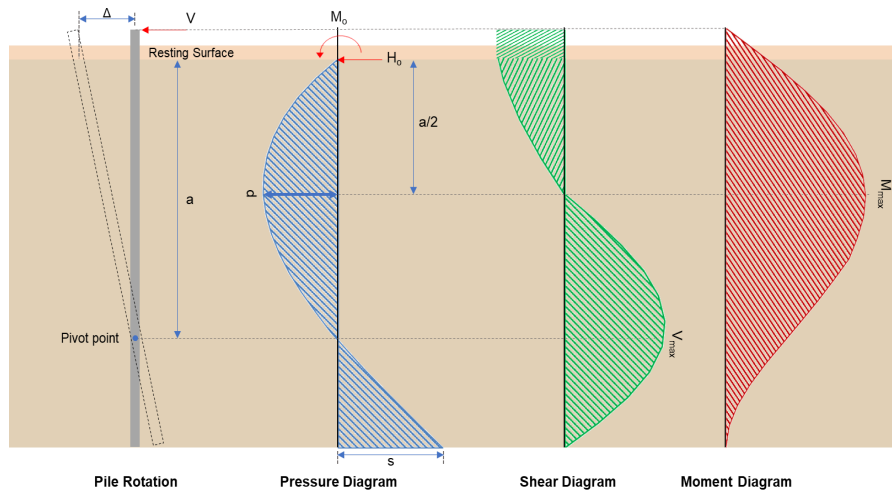
$$\text{Ratio} = \frac{s}{p_s}$$

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

$$Ratio = \frac{(0.0025425 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.0030818$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.207 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35143 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.719 \text{ kipft}) + ((-2.207 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.2546 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2546 \text{ kipft/ft})}{(-0.35143 \text{ kip/ft})}$$

$$E = 12.106 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2546 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.35143 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.2546 \text{ kipft/ft})) + (4 \times (-0.35143 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7732 \text{ ft}$$

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

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

$$V_{max} = ((-0.35143 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7732 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7732 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.4043 \text{ kip}$$

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

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

$$M_{max} = ((-0.35143 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(12.106 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (12.106 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7732 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 16.908 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.011 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0017516 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.033 \text{ kipft}) + ((0.011 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0052548 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0052548 \text{ kipft/ft})}{(0.0017516 \text{ kip/ft})}$$

$$E = 3 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0052548 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.0017516 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.0052548 \text{ kipft/ft})) + (4 \times (0.0017516 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9188 \text{ ft}$$

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

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

$$V_{max} = ((0.0017516 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9188 \text{ ft})}{(5.5 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9188 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.011424 \text{ kip}$$

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

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

$$M_{max} = ((0.0017516 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (3 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9188 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.027976 \text{ kipft}$$

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

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.928 \text{ kip})}{(0.65)(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.333 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.333 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Ties: #3(0.375 in) - 10 in

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2

ϕP_N - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(7.928 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0029635$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.928 \text{ kip} \rightarrow 7928 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7928 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.54 \text{ kip}$$

22.5.5.1.2

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.54 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.54 \text{ kip}$$

| | | |
|-----------------|--|---|
| <p>22.5.1.2</p> | <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{ytik} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((119.54 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.78 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 6.4043 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(6.4043 \text{ kip})}{(110.78 \text{ kip})}$ $\text{Ratio} = 0.057809$ <p>Considering z-direction:</p> <p>$V_{max} = 0.011424 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.011424 \text{ kip})}{(110.78 \text{ kip})}$ $\text{Ratio} = 0.00010312$ | <p>Status: PASS Ratio: 0.060</p> <p>Status: PASS Ratio: 0.000</p> |
| | <p>Flexural Strength (ACI 318-19, LFRD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ | |

| | | |
|------------------|--|---|
| <p>14.5.2.1b</p> | <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction: $M_{max} = 16.908 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(16.908 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.06774$ | <p>Status: PASS Ratio: 0.070</p> |
| | <p>Considering z-direction: $M_{max} = 0.027976 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.027976 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.00011208$ | <p>Status: PASS Ratio: 0.000</p> |