

Project Details

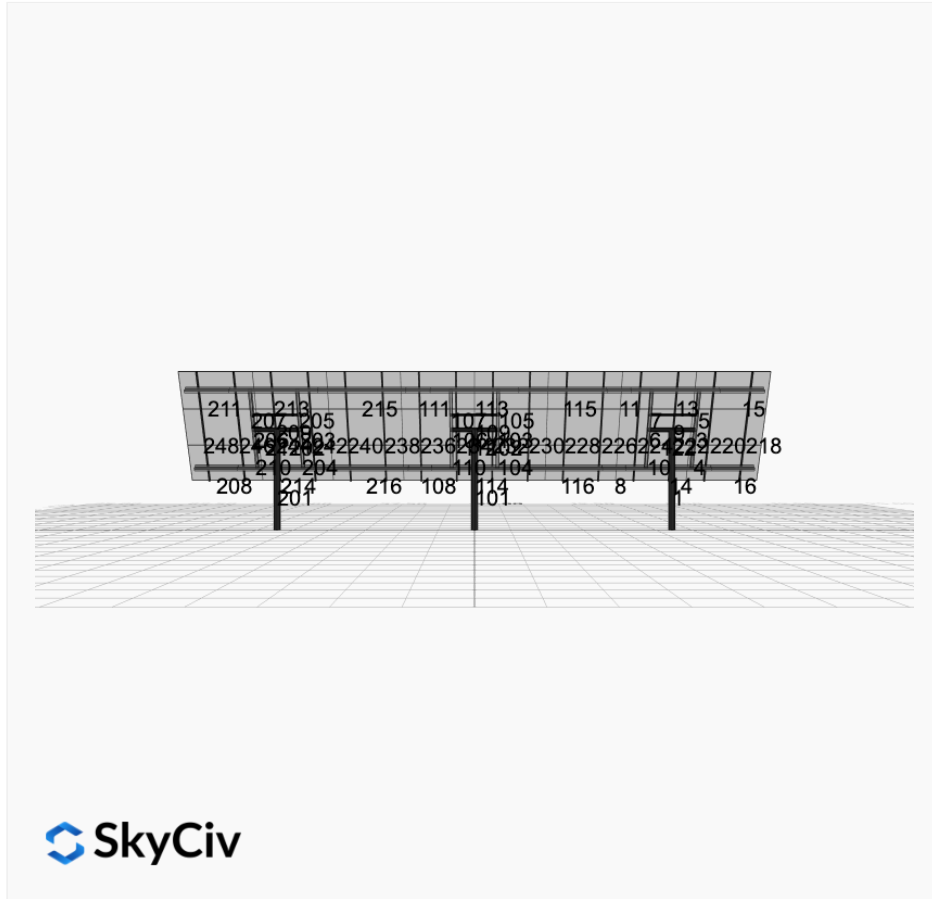


Project Name: Walz - Sedimentary - Square - V1Jb **Date:** Mon Aug 19 2024

Location: Rowley Rd, Caledonia, WI 53901, USA **Number of Modules:** 24

Unique ID: 3P-17-6TOP-SD-45-L-3Hx8W-9G31 **Number of Poles:** 3

Dealer: _____ **Date Sold:** _____



| | |
|-----------------------------|----------|
| Array Dimensions N/S | 10.50 ft |
| Array Dimensions E/W | 50.00 ft |
| Winter Tilt Angle | 62 |
| Front Edge Clearance | 4 ft |

MT Solar Bill of Materials (3P-17-6TOP-SD-45-L-3Hx8W-9G31)

| Part | Short Description | BOM Qty |
|--------------------|-----------------------|---------|
| MTS-PC-6 | 6IN Pole Cap Assembly | 3 |
| MTS-HF-SD | H-Frame Assembly-SD | 3 |
| MTS-SD-Wing-45 | 45IN SD Wing | 4 |
| MTS-SD-Splice-57 | 57IN SD Splice | 8 |
| MTS-CLAMP-HOOK-4PK | Hook Clamp | 8 |

Rail Bill of Materials

| Part | Qty |
|------------------|-----|
| Rails (125in) | 16 |
| Rail Attachment | 32 |
| Module Mid Clamp | 32 |
| Module End Clamp | 32 |

| Part | Qty |
|------------|-----|
| Ground Lug | 8 |

Site Details:



Site Address: Rowley Rd, Caledonia, WI 53901, USA

Array Specification

| | |
|-----------------------------|-----------|
| Duty Classification: | SD |
| Module Width: | 41.50 in |
| Module Length: | 74.00in |
| Number of Rows: | 3 |
| Number of Columns: | 8 |
| Total Number of Modules: | 24 |
| Winter Tilt Angle: | 62 |
| Front Edge Clearance: | 4 |
| Total Array Height at Tilt: | 13.27 ft |
| Total Frame Length: | 49.00 ft |
| Frame Weight: | 2303 lbs |
| Array Dimensions N/S: | 10.50 ft |
| Array Dimensions E/W: | 50.00 ft |
| Rail Length: | 126.00 in |
| Rail Spacing: | 3.13 ft |

Support Specifications

| | |
|--------------------------|-----------------|
| Pole Size: | 6in Pipe Sch 40 |
| Pole Length above Grade: | 8.64 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: 3.75 ft Pile 2: 3.75 ft Pile 3: 3.75 ft |
| Foundation Volume: | 6.667 y ³ |

Site Info

| | |
|----------------------|-------------------------------------|
| Risk Category: | I |
| Exposure: | B |
| Soil Classification: | sedimentary |
| Site Location: | Rowley Rd, Caledonia, WI 53901, USA |
| Wind Speed: | 100 mph |
| Snow Load: | 30 psf |

Design Disclaimer

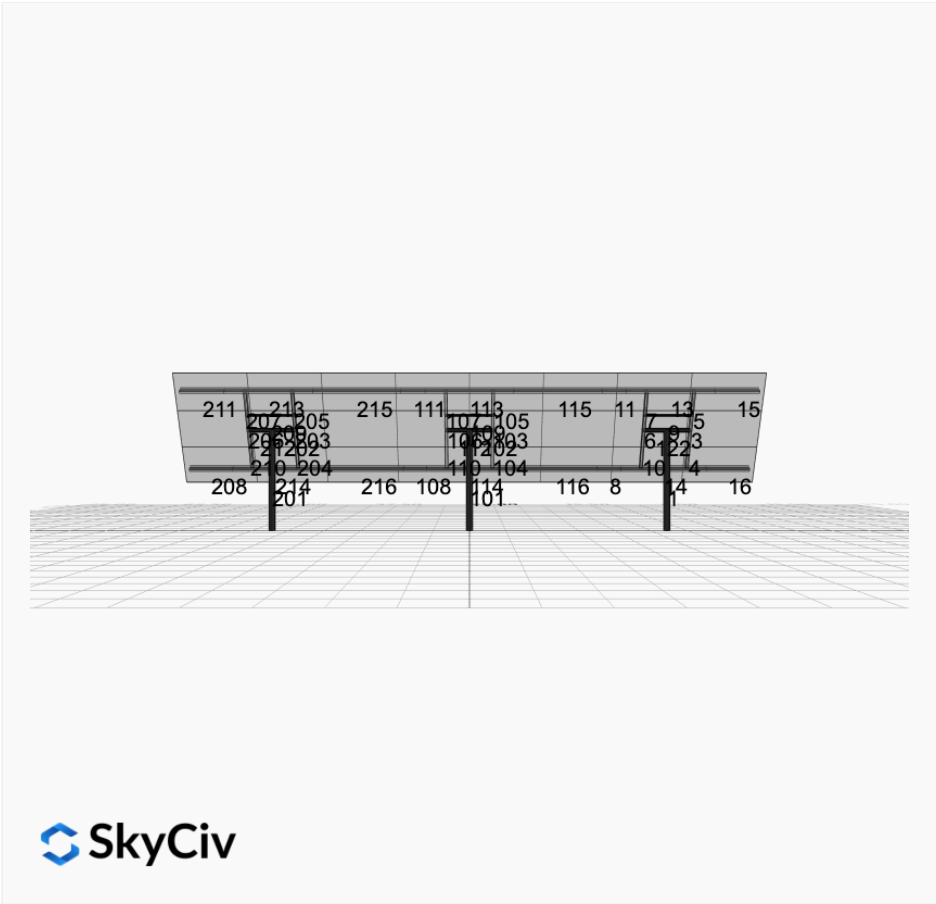
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

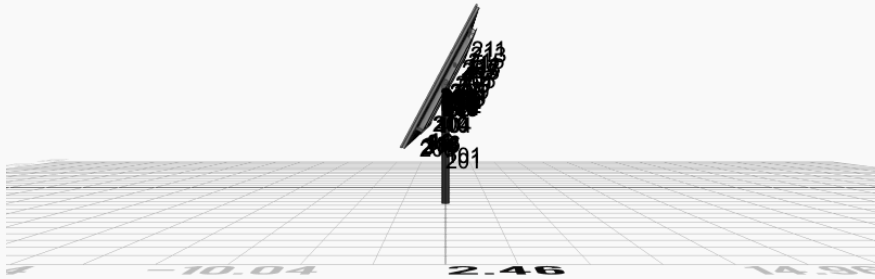
AutoDesigner Input

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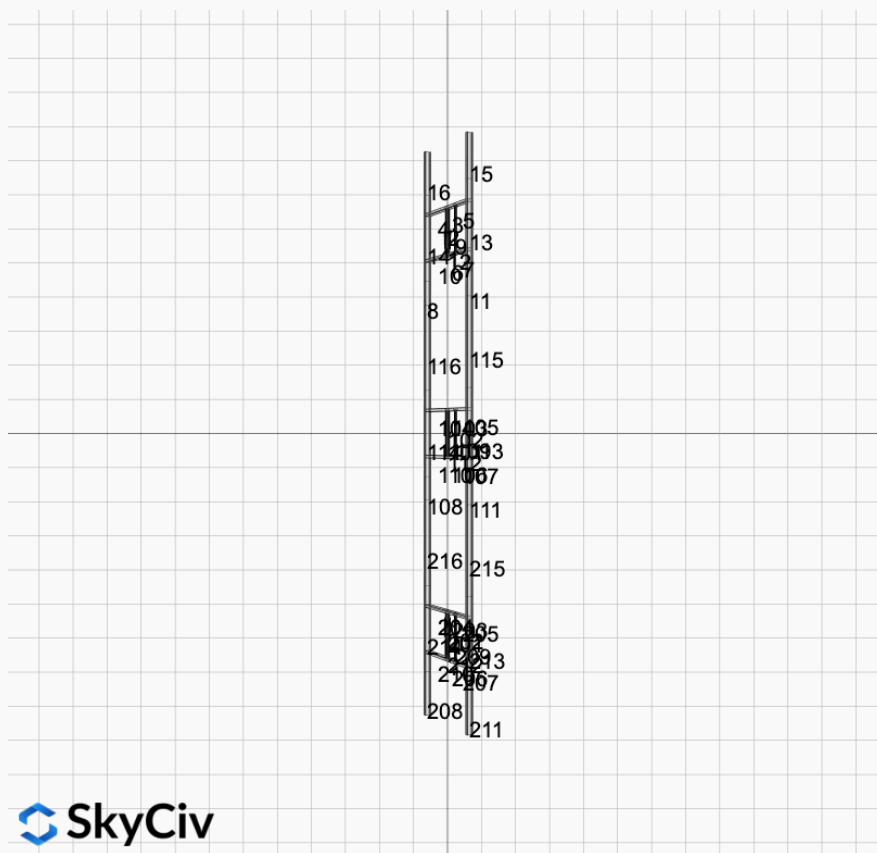
Design Notes:

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

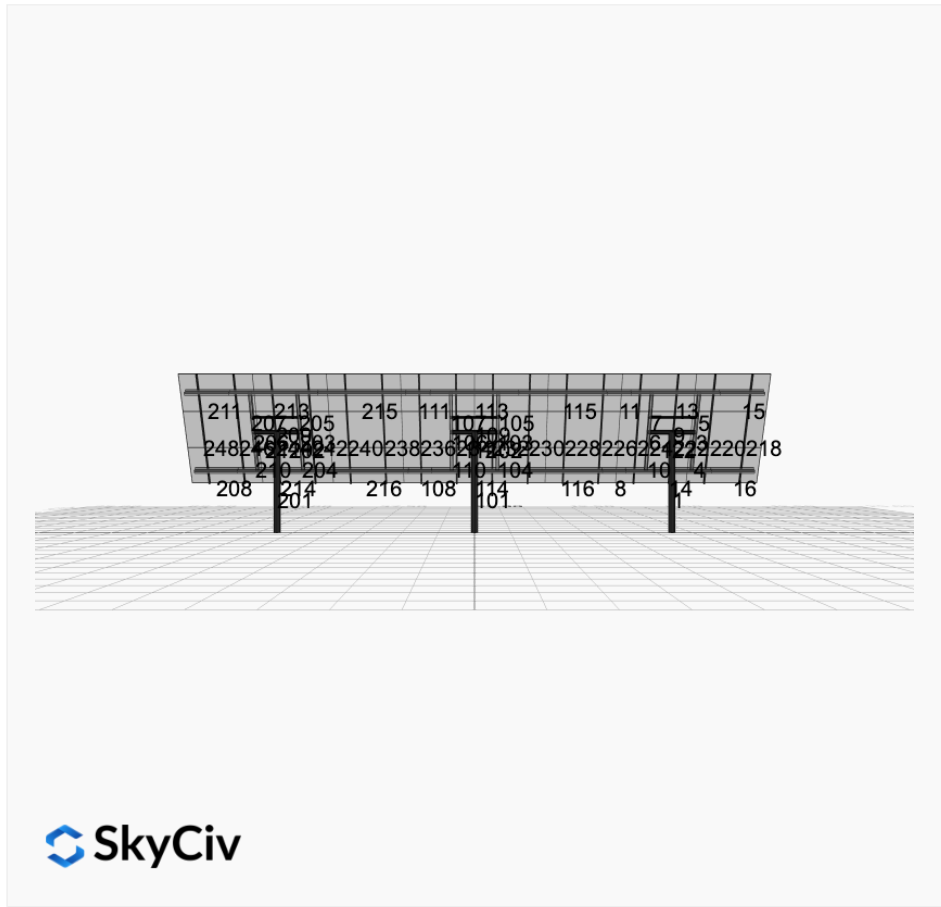
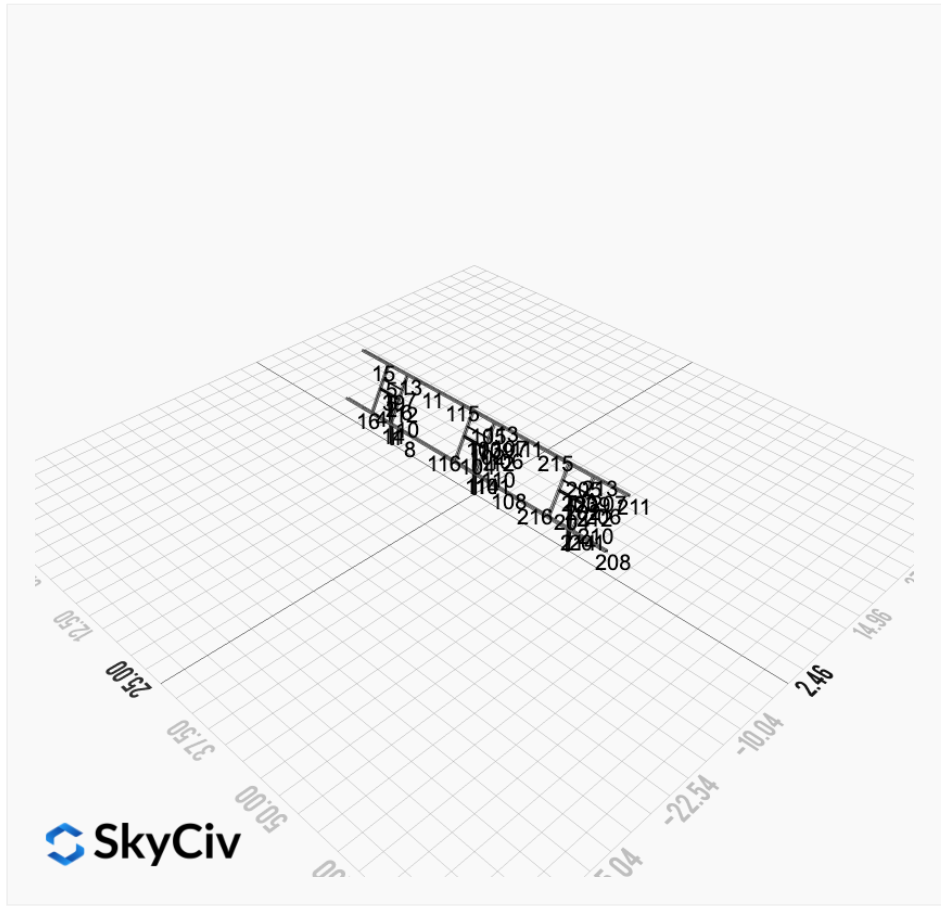




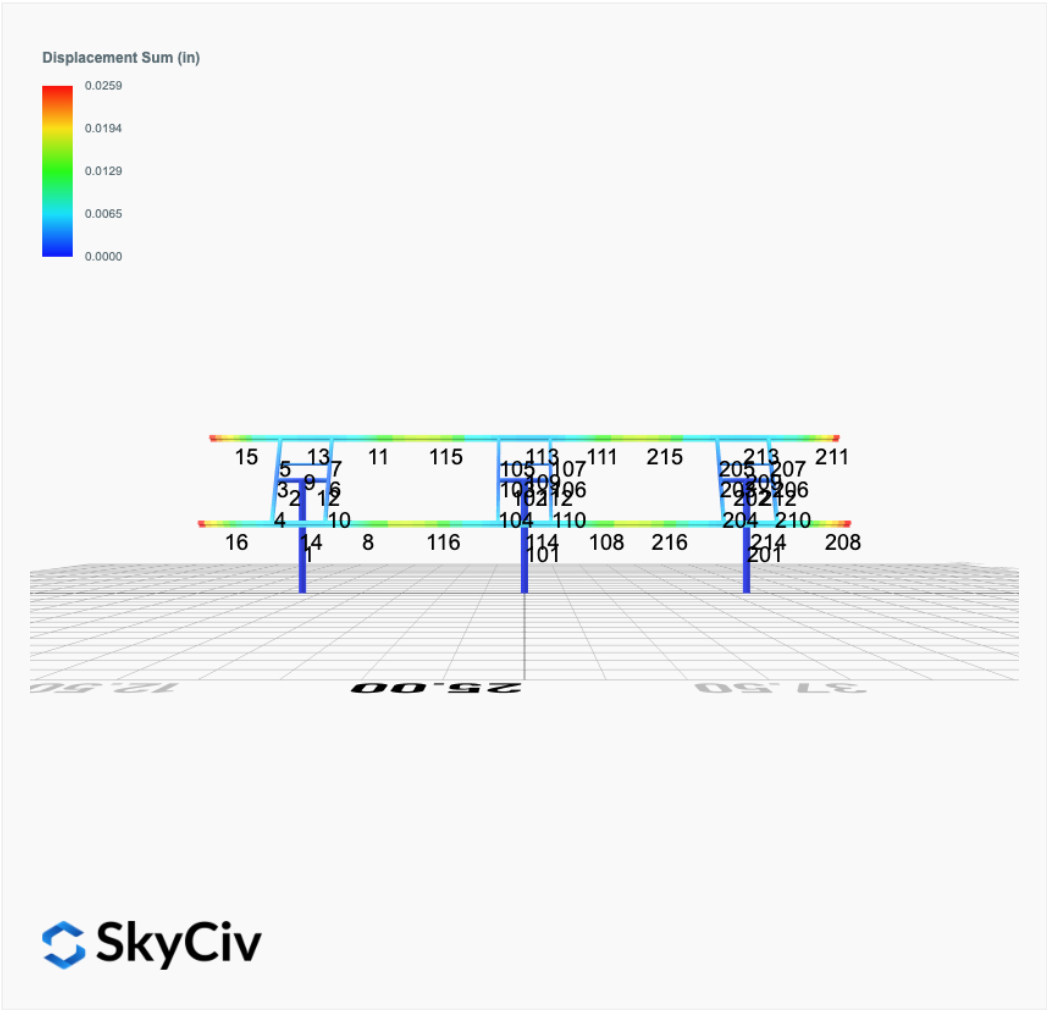
 SkyCiv



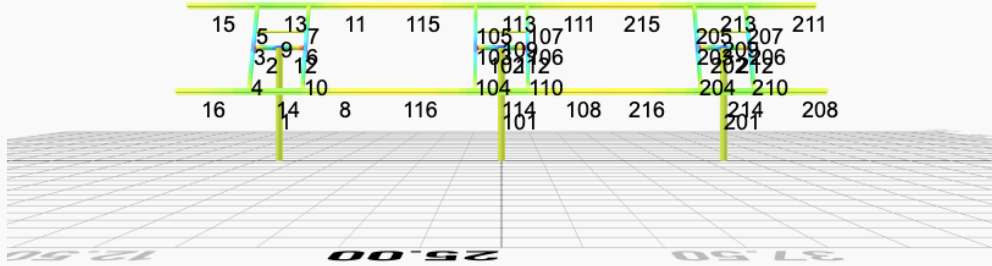
 SkyCiv

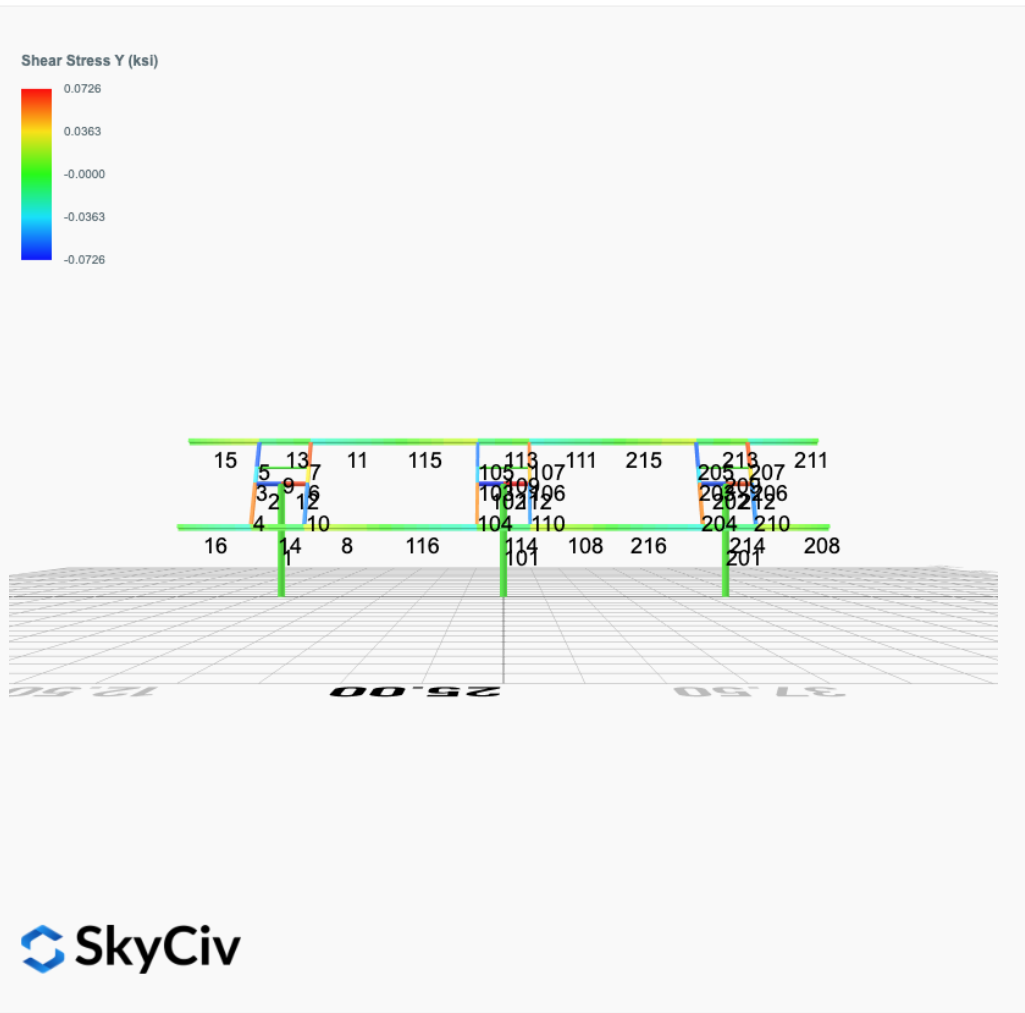


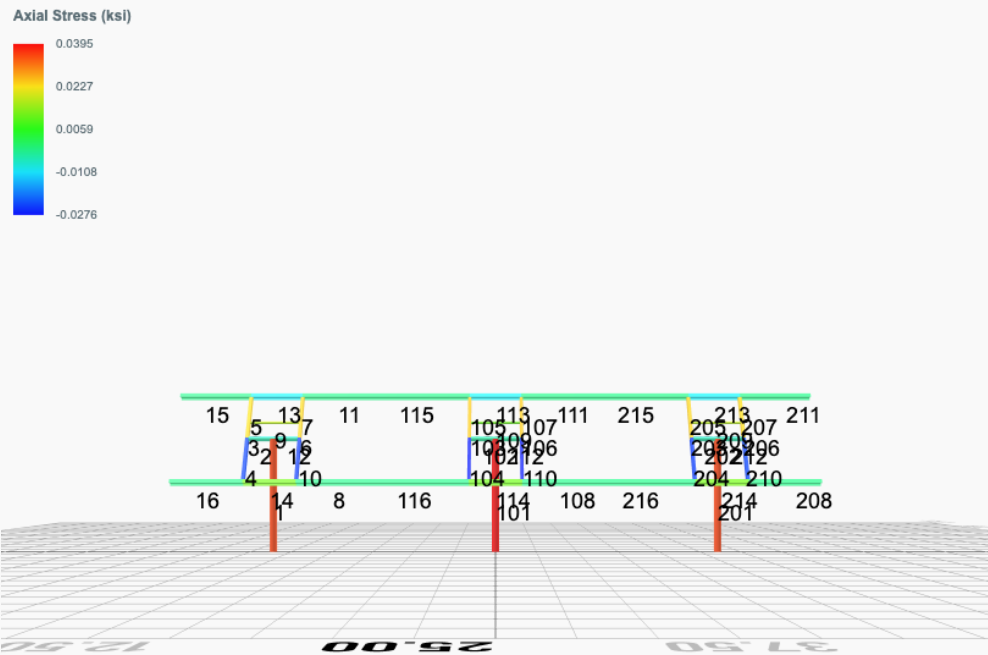
FEM Results (Envelope Worst Case for each member)



Top Bending Stress Z (ksi)







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 | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 2. D + L | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 3. D + (S or Lr or R) | -0.0045 | 1.6573 | -0.0007 | -0.0005 | 0.0268 | 0.0441 |
| ULS: 3. D + (S or Lr or R) | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0043 | 1.6052 | -0.0007 | -0.0005 | 0.0257 | 0.0428 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 5b. D + 0.7E | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0043 | 1.6052 | -0.0007 | -0.0005 | 0.0257 | 0.0428 |
| ULS: 8. 0.6D + 0.7E | -0.0023 | 0.8692 | -0.0004 | -0.0003 | 0.0136 | 0.0234 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.4127 | 2.1961 | -0.0047 | -0.0104 | 0.0411 | 12.2831 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.4050 | 0.7013 | 0.0036 | 0.0095 | 0.0039 | -12.0711 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0610 | 2.1657 | -0.0037 | -0.0080 | 0.0396 | 9.2259 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0043 | 1.6052 | -0.0007 | -0.0005 | 0.0257 | 0.0428 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0523 | 1.0446 | 0.0024 | 0.0070 | 0.0117 | -9.0397 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0043 | 1.6052 | -0.0007 | -0.0005 | 0.0257 | 0.0428 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0605 | 2.0093 | -0.0037 | -0.0079 | 0.0365 | 9.2221 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0528 | 0.8882 | 0.0025 | 0.0070 | 0.0086 | -9.0436 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0038 | 1.4487 | -0.0006 | -0.0005 | 0.0227 | 0.0390 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.4112 | 1.6166 | -0.0045 | -0.0102 | 0.0320 | 12.2675 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0023 | 0.8692 | -0.0004 | -0.0003 | 0.0136 | 0.0234 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.4065 | 0.1219 | 0.0038 | 0.0097 | -0.0052 | -12.0867 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0023 | 0.8692 | -0.0004 | -0.0003 | 0.0136 | 0.0234 |

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 | 3.0885 |
| Shear X | -2.3533 |
| Shear Z | -0.0075 |
| Moment X | -0.0170 |
| Moment Y (Twist) | 0.0595 |
| Moment Z | 20.6422 |

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 | 2.1961 |
| Shear X | -1.4127 |
| Shear Z | -0.0047 |
| Moment X | -0.0104 |
| Moment Y (Twist) | 0.0411 |
| Moment Z | 12.2831 |

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 | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 2. D + L | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 3. D + (S or Lr or R) | 0.0090 | 1.7331 | -0.0000 | 0.0000 | 0.0000 | -0.0549 |
| ULS: 3. D + (S or Lr or R) | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0086 | 1.6780 | -0.0000 | 0.0000 | 0.0000 | -0.0523 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---------|--------|---------|--------|--------|----------|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 5b. D + 0.7E | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0086 | 1.6780 | -0.0000 | 0.0000 | 0.0000 | -0.0523 |
| ULS: 8. 0.6D + 0.7E | 0.0046 | 0.9077 | -0.0000 | 0.0000 | 0.0000 | -0.0269 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.4271 | 2.2791 | -0.0000 | 0.0000 | 0.0000 | 12.3933 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.4425 | 0.7464 | -0.0000 | 0.0000 | 0.0000 | -12.3464 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0674 | 2.2528 | -0.0000 | 0.0000 | 0.0000 | 9.2762 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0086 | 1.6780 | -0.0000 | 0.0000 | 0.0000 | -0.0523 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0848 | 1.1033 | -0.0000 | 0.0000 | 0.0000 | -9.2786 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0086 | 1.6780 | -0.0000 | 0.0000 | 0.0000 | -0.0523 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0684 | 2.0875 | -0.0000 | 0.0000 | 0.0000 | 9.2838 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0838 | 0.9380 | -0.0000 | 0.0000 | 0.0000 | -9.2710 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0076 | 1.5128 | -0.0000 | 0.0000 | 0.0000 | -0.0448 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.4301 | 1.6740 | -0.0000 | 0.0000 | 0.0000 | 12.4112 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0046 | 0.9077 | -0.0000 | 0.0000 | 0.0000 | -0.0269 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.4395 | 0.1413 | -0.0000 | 0.0000 | 0.0000 | -12.3285 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0046 | 0.9077 | -0.0000 | 0.0000 | 0.0000 | -0.0269 |

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 | 3.2026 |
| Shear X | -2.4009 |
| Shear Z | -0.0000 |
| Moment X | 0.0000 |
| Moment Y (Twist) | 0.0001 |
| Moment Z | 20.8618 |

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 | 2.2791 |
| Shear X | -1.4425 |
| Shear Z | -0.0000 |
| Moment X | 0.0000 |
| Moment Y (Twist) | 0.0000 |
| Moment Z | 12.4112 |

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 | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 2. D + L | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 3. D + (S or Lr or R) | -0.0045 | 1.6573 | 0.0007 | 0.0005 | -0.0268 | 0.0441 |
| ULS: 3. D + (S or Lr or R) | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0043 | 1.6052 | 0.0007 | 0.0005 | -0.0257 | 0.0428 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 5b. D + 0.7E | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0043 | 1.6052 | 0.0007 | 0.0005 | -0.0257 | 0.0428 |
| ULS: 8. 0.6D + 0.7E | -0.0023 | 0.8692 | 0.0004 | 0.0003 | -0.0136 | 0.0234 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -1.4127 | 2.1961 | 0.0047 | 0.0104 | -0.0411 | 12.2831 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 1.4050 | 0.7013 | -0.0036 | -0.0095 | -0.0039 | -12.0711 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |

| 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 | -1.0610 | 2.1657 | 0.0037 | 0.0080 | -0.0396 | 9.2259 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0043 | 1.6052 | 0.0007 | 0.0005 | -0.0257 | 0.0428 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0523 | 1.0446 | -0.0024 | -0.0070 | -0.0117 | -9.0397 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0043 | 1.6052 | 0.0007 | 0.0005 | -0.0257 | 0.0428 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.0605 | 2.0093 | 0.0037 | 0.0079 | -0.0365 | 9.2221 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.0528 | 0.8882 | -0.0025 | -0.0070 | -0.0086 | -9.0436 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0038 | 1.4487 | 0.0006 | 0.0005 | -0.0227 | 0.0390 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -1.4112 | 1.6166 | 0.0045 | 0.0102 | -0.0320 | 12.2675 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0023 | 0.8692 | 0.0004 | 0.0003 | -0.0136 | 0.0234 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 1.4065 | 0.1219 | -0.0038 | -0.0097 | 0.0052 | -12.0867 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0023 | 0.8692 | 0.0004 | 0.0003 | -0.0136 | 0.0234 |

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 | 3.0885 |
| Shear X | -2.3533 |
| Shear Z | 0.0075 |
| Moment X | 0.0170 |
| Moment Y (Twist) | 0.0595 |
| Moment Z | 20.6427 |

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 | 2.1961 |
| Shear X | -1.4127 |
| Shear Z | 0.0047 |
| Moment X | 0.0104 |
| Moment Y (Twist) | 0.0411 |
| Moment Z | 12.2831 |

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) | | | | | |
| 1 | 2in Pipe Sch 40 | 2.38 | 0.15 | | | | | |
| 4 | 4in Pipe Sch 40 | 4.50 | 0.24 | | | | | |
| 7 | 6in Pipe Sch 40 | 6.63 | 0.28 | | | | | |
| | | | | | | | | |
| ID | Name | d (in) | b (in) | t_w (in) | t_b (in) | r (in) | | |
| 15 | HSS5x3x1/8 | 5.00 | 3.00 | 0.12 | 0.12 | 0.12 | | |
| | | | | | | | | |
| ID | Name | d (in) | t_w (in) | b_t (in) | b_b (in) | t_t (in) | t_b (in) | r (in) |
| 18 | W6x9 | 5.90 | 0.17 | 3.94 | 3.94 | 0.21 | 0.21 | 0.25 |

| 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) |
| - | - | - | - | - | - | - | - | - |

| | | | | | | | | |
|----|-----------------|------|-------|-------|-------|-------|-------|-------|
| 1 | 2in Pipe Sch 40 | 1.07 | 1.33 | 0.67 | 0.67 | 0.00 | 0.76 | 0.76 |
| 4 | 4in Pipe Sch 40 | 3.17 | 14.47 | 7.23 | 7.23 | 0.00 | 4.31 | 4.31 |
| 7 | 6in Pipe Sch 40 | 5.58 | 56.28 | 28.14 | 28.14 | 0.00 | 11.28 | 11.28 |
| 15 | HSS5x3x1/8 | 1.77 | 6.02 | 2.75 | 6.03 | 0.51 | 2.07 | 2.93 |
| 18 | W6x9 | 2.68 | 0.04 | 2.20 | 16.40 | 17.70 | 1.72 | 6.23 |

| Member Properties | | | | | | | | | | |
|-------------------|------------|-----------------------|-----------------------|---------------------|---|------|------|-----|--|--|
| Member ID | Section ID | K _z L (ft) | K _y L (ft) | L _b (ft) | C _b | LS T | LS C | L D | | |
| 1 | 7 | 18.13 | 18.13 | 8.64 | - | 300 | 200 | 1 | | |
| 2 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 | | |
| 3 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.19 | 300 | 200 | 1 | | |
| 4 | 15 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.65,1.69,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 5 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 6 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.19 | 300 | 200 | 1 | | |
| 7 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 8 | 18 | 1.33 | 1.33 | 2.05 | 1.95,1.95,1.95,1.95,1.95,1.95,1.93,1.95,1.91,1.95,1.92,1.95,1.91,1.95,1.93,1.95,1.87,1.95,1.93,1.95,1.89,1.95,1.92,1.95,1.91,1.95 | 300 | 200 | 1 | | |
| 9 | 1 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 | | |
| 10 | 15 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.65,1.69,1.67,1.68,1.66,1.69 | 300 | 200 | 1 | | |
| 11 | 18 | 1.33 | 1.33 | 2.05 | 1.93,1.93,1.93,1.93,1.93,1.93,1.95,1.93,1.97,1.93,1.95,1.93,1.97,1.93,1.95,1.93,2.01,1.93,1.95,1.93,1.99,1.93,1.95,1.93,1.97,1.93 | 300 | 200 | 1 | | |
| 12 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 | | |
| 13 | 18 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.12,1.12,1.12 | 300 | 200 | 1 | | |
| 14 | 18 | 4.88 | 4.00 | 7.50 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.12,1.12,1.12 | 300 | 200 | 1 | | |
| 15 | 18 | 7.88 | 7.88 | 3.75 | 2.33,2.33 | 300 | 200 | 1 | | |
| 16 | 18 | 7.88 | 7.88 | 3.75 | 2.33,2.33 | 300 | 200 | 1 | | |
| 101 | 7 | 18.13 | 18.13 | 8.64 | - | 300 | 200 | 1 | | |
| 102 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 | | |
| 103 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.19 | 300 | 200 | 1 | | |
| 104 | 15 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 105 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 106 | 15 | 0.92 | 0.92 | 1.42 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.19 | 300 | 200 | 1 | | |
| 107 | 15 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 108 | 18 | 1.33 | 1.33 | 2.05 | 1.61,1.61,1.61,1.61,1.61,1.61,1.57,1.61,1.55,1.61,1.57,1.61,1.55,1.61,1.58,1.61,1.50,1.61,1.58,1.61,1.52,1.61,1.57,1.61,1.55,1.61 | 300 | 200 | 1 | | |
| 109 | 1 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 | | |
| 110 | 15 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.64,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 | | |
| 111 | 18 | 1.33 | 1.33 | 2.05 | 1.72,1.72,1.72,1.72,1.72,1.72,1.55,1.72,1.47,1.72,1.55,1.72,1.47,1.72,1.58,1.72,1.34,1.72,1.57,1.72,1.40,1.72,1.54,1.72,1.48,1.72 | 300 | 200 | 1 | | |
| 112 | 4 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 | | |

| | | | | | | | | |
|-----|----|-----------|-----------|----------|---|---------|---------|---|
| 113 | 18 | 4.88 | 4.00 | 7.5 0 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.09,1.06,1.06,1.06,1.0 8,1.06,1.06,1.06,1.07,1.06 | 30 0 | 20 0 | 1 |
| 114 | 18 | 4.88 | 4.00 | 7.5 0 | 1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.0 7,1.06,1.06,1.06,1.06,1.06 | 30 0 | 20 0 | 1 |
| 115 | 18 | 4.84 | 4.84 | 7.4 5 | 1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.14,1.11,1.14,1.12,1.14,1.11,1.14,1.12,1.14,1.08,1.14,1.12,1.14,1.1 0,1.14,1.12,1.14,1.11,1.14 | 30 0 | 20 0 | 1 |
| 116 | 18 | 4.84 | 4.84 | 7.4 5 | 1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.13,1.12,1.13,1.12,1.13,1.12,1.13,1.11,1.13,1.12,1.13,1.1 2,1.13,1.12,1.13,1.12,1.13 | 30 0 | 20 0 | 1 |
| 201 | 7 | 18.1 3 | 18.1 3 | 8.6 4 | - | 30 0 | 20 0 | 1 |
| 202 | 4 | 1.30 | 1.30 | 2.0 0 | - | 30 0 | 20 0 | 1 |
| 203 | 15 | 0.92 | 0.92 | 1.4 2 | 1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.1 7,1.19,1.18,1.19,1.18,1.19 | 30 0 | 20 0 | 1 |
| 204 | 15 | 2.44 | 2.44 | 3.7 5 | 1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.6 5,1.69,1.67,1.69,1.66,1.69 | 30 0 | 20 0 | 1 |
| 205 | 15 | 1.52 | 1.52 | 2.3 3 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.6 6,1.68,1.67,1.68,1.66,1.68 | 30 0 | 20 0 | 1 |
| 206 | 15 | 0.92 | 0.92 | 1.4 2 | 1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.16,1.19,1.18,1.19,1.1 7,1.19,1.18,1.19,1.18,1.19 | 30 0 | 20 0 | 1 |
| 207 | 15 | 1.52 | 1.52 | 2.3 3 | 1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.6 6,1.68,1.67,1.68,1.66,1.68 | 30 0 | 20 0 | 1 |
| 208 | 18 | 7.88 | 7.88 | 3.7 5 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33 | 30 0 | 20 0 | 1 |
| 209 | 1 | 2.60 | 2.60 | 4.0 0 | - | 30 0 | 20 0 | 1 |
| 210 | 15 | 2.44 | 2.44 | 3.7 5 | 1.69,1.68,1.69,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.6 5,1.69,1.67,1.68,1.66,1.68 | 30 0 | 20 0 | 1 |
| 211 | 18 | 7.88 | 7.88 | 3.7 5 | 2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33 | 30 0 | 20 0 | 1 |
| 212 | 4 | 1.30 | 1.30 | 2.0 0 | - | 30 0 | 20 0 | 1 |
| 213 | 18 | 4.88 | 4.00 | 7.5 0 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.1 1,1.12,1.12,1.12,1.12,1.12 | 30 0 | 20 0 | 1 |
| 214 | 18 | 4.88 | 4.00 | 7.5 0 | 1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.1 2,1.12,1.12,1.12,1.12,1.12 | 30 0 | 20 0 | 1 |
| 215 | 18 | 4.84 | 4.84 | 7.4 5 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.1 7,1.16,1.16,1.16,1.16,1.16 | 30 0 | 20 0 | 1 |
| 216 | 18 | 4.84 | 4.84 | 7.4 5 | 1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.1 6,1.16,1.16,1.16,1.16,1.16 | 30 0 | 20 0 | 1 |

Member Design Capacity

| Member ID | $\Phi_t P_n$ (kip) | $\Phi_c P_n$ (kip) | $\Phi_b M_{zn}$ (k-ft) | $\Phi_b M_{yn}$ (k-ft) | $\Phi_v V_{yn}$ (kip) | $\Phi_v V_{zn}$ (kip) |
|-----------|--------------------|--------------------|------------------------|------------------------|-----------------------|-----------------------|
| 1 | 251.16 | 126.39 | 42.30 | 42.30 | 75.35 | 75.35 |
| 2 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 3 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 4 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 5 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 6 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 7 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 8 | 120.60 | 115.40 | 23.36 | 6.45 | 30.09 | 45.74 |
| 9 | 48.35 | 43.11 | 2.85 | 2.85 | 14.51 | 14.51 |
| 10 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 11 | 120.60 | 115.40 | 23.36 | 6.45 | 30.09 | 45.74 |
| 12 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 13 | 120.60 | 84.03 | 19.59 | 6.45 | 30.09 | 45.74 |
| 14 | 120.60 | 84.03 | 19.63 | 6.45 | 30.09 | 45.74 |
| 15 | 120.60 | 54.44 | 23.36 | 6.45 | 30.09 | 45.74 |
| 16 | 120.60 | 54.44 | 23.36 | 6.45 | 30.09 | 45.74 |

| | | | | | | |
|-----|--------|--------|-------|-------|-------|-------|
| 101 | 251.10 | 120.39 | 42.30 | 42.30 | 75.35 | 75.35 |
| 102 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 103 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 104 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 105 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 106 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 107 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 108 | 120.60 | 115.40 | 23.36 | 6.45 | 30.09 | 45.74 |
| 109 | 48.35 | 43.11 | 2.85 | 2.85 | 14.51 | 14.51 |
| 110 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 111 | 120.60 | 115.40 | 23.36 | 6.45 | 30.09 | 45.74 |
| 112 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 113 | 120.60 | 84.03 | 18.60 | 6.45 | 30.09 | 45.74 |
| 114 | 120.60 | 84.03 | 18.63 | 6.45 | 30.09 | 45.74 |
| 115 | 120.60 | 84.26 | 19.16 | 6.45 | 30.09 | 45.74 |
| 116 | 120.60 | 84.26 | 19.67 | 6.45 | 30.09 | 45.74 |
| 201 | 251.16 | 126.39 | 42.30 | 42.30 | 75.35 | 75.35 |
| 202 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 203 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 204 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 205 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 206 | 79.65 | 74.02 | 10.99 | 6.26 | 29.14 | 16.61 |
| 207 | 79.65 | 73.44 | 10.99 | 6.26 | 29.14 | 16.61 |
| 208 | 120.60 | 54.44 | 23.36 | 6.45 | 30.09 | 45.74 |
| 209 | 48.35 | 43.11 | 2.85 | 2.85 | 14.51 | 14.51 |
| 210 | 79.65 | 72.01 | 10.99 | 6.26 | 29.14 | 16.61 |
| 211 | 120.60 | 54.44 | 23.36 | 6.45 | 30.09 | 45.74 |
| 212 | 142.83 | 141.72 | 16.17 | 16.17 | 42.85 | 42.85 |
| 213 | 120.60 | 84.03 | 19.58 | 6.45 | 30.09 | 45.74 |
| 214 | 120.60 | 84.03 | 19.64 | 6.45 | 30.09 | 45.74 |
| 215 | 120.60 | 84.26 | 20.47 | 6.45 | 30.09 | 45.74 |
| 216 | 120.60 | 84.26 | 20.45 | 6.45 | 30.09 | 45.74 |

Design Ratio

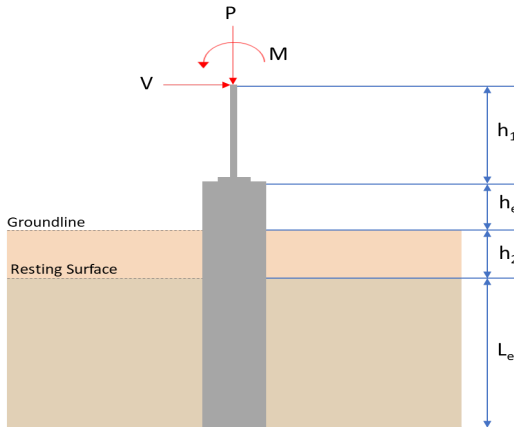
| Member ID | P | M _z | M _y | V _y | V _z | (P,M _z ,M _y) | Worst LC | KL/r | δ | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|--------------|--------------|--------|
| 1 | 0.024 | 0.488 | 0.001 | 0.031 | 0.000 | 0.501 | #13 | 0.485 | Not Required | Pass |
| 2 | 0.001 | 0.140 | 0.145 | 0.034 | 0.028 | 0.285 | #13 | 0.034 | Not Required | Pass |
| 3 | 0.005 | 0.293 | 0.043 | 0.030 | 0.008 | 0.334 | #13 | 0.044 | Not Required | Pass |
| 4 | 0.005 | 0.292 | 0.075 | 0.029 | 0.013 | 0.340 | #13 | 0.078 | Not Required | Pass |
| 5 | 0.005 | 0.181 | 0.076 | 0.029 | 0.014 | 0.195 | #13 | 0.073 | Not Required | Pass |
| 6 | 0.006 | 0.289 | 0.045 | 0.029 | 0.008 | 0.331 | #13 | 0.044 | Not Required | Pass |
| 7 | 0.005 | 0.179 | 0.074 | 0.029 | 0.015 | 0.195 | #13 | 0.073 | Not Required | Pass |
| 8 | 0.000 | 0.026 | 0.031 | 0.017 | 0.005 | 0.054 | #13 | 0.088 | Not Required | Pass |
| 9 | 0.002 | 0.015 | 0.030 | 0.001 | 0.000 | 0.046 | #13 | 0.198 | Not Required | Pass |
| 10 | 0.005 | 0.287 | 0.072 | 0.029 | 0.013 | 0.339 | #13 | 0.078 | Not Required | Pass |
| 11 | 0.000 | 0.026 | 0.031 | 0.017 | 0.005 | 0.053 | #13 | 0.088 | Not Required | Pass |
| 12 | 0.001 | 0.137 | 0.142 | 0.034 | 0.027 | 0.279 | #13 | 0.034 | Not Required | Pass |
| 13 | 0.002 | 0.084 | 0.110 | 0.023 | 0.007 | 0.174 | #13 | 0.265 | Not Required | Pass |
| 14 | 0.003 | 0.086 | 0.110 | 0.023 | 0.007 | 0.174 | #13 | 0.177 | Not Required | Pass |
| 15 | 0.000 | 0.031 | 0.051 | 0.013 | 0.004 | 0.075 | #13 | Not Required | Not Required | Pass |

| | | | | | | | | | | |
|-----|-------|-------|-------|-------|-------|-------|-----|--------------|--------------|------|
| 16 | 0.000 | 0.031 | 0.051 | 0.013 | 0.004 | 0.075 | #13 | Not Required | Not Required | Pass |
| 101 | 0.025 | 0.493 | 0.000 | 0.032 | 0.000 | 0.506 | #13 | 0.485 | Not Required | Pass |
| 102 | 0.000 | 0.142 | 0.143 | 0.035 | 0.028 | 0.286 | #13 | 0.034 | Not Required | Pass |
| 103 | 0.006 | 0.297 | 0.049 | 0.030 | 0.010 | 0.343 | #13 | 0.044 | Not Required | Pass |
| 104 | 0.005 | 0.297 | 0.069 | 0.030 | 0.012 | 0.347 | #13 | 0.078 | Not Required | Pass |
| 105 | 0.006 | 0.184 | 0.070 | 0.030 | 0.013 | 0.197 | #13 | 0.073 | Not Required | Pass |
| 106 | 0.006 | 0.297 | 0.049 | 0.030 | 0.010 | 0.343 | #13 | 0.044 | Not Required | Pass |
| 107 | 0.006 | 0.184 | 0.070 | 0.030 | 0.013 | 0.197 | #13 | 0.073 | Not Required | Pass |
| 108 | 0.000 | 0.031 | 0.031 | 0.016 | 0.005 | 0.057 | #13 | 0.088 | Not Required | Pass |
| 109 | 0.001 | 0.012 | 0.028 | 0.001 | 0.000 | 0.040 | #13 | 0.198 | Not Required | Pass |
| 110 | 0.005 | 0.297 | 0.069 | 0.030 | 0.012 | 0.347 | #13 | 0.078 | Not Required | Pass |
| 111 | 0.000 | 0.031 | 0.031 | 0.016 | 0.005 | 0.057 | #13 | 0.088 | Not Required | Pass |
| 112 | 0.000 | 0.142 | 0.143 | 0.035 | 0.028 | 0.286 | #13 | 0.034 | Not Required | Pass |
| 113 | 0.002 | 0.060 | 0.096 | 0.022 | 0.007 | 0.137 | #13 | 0.265 | Not Required | Pass |
| 114 | 0.002 | 0.063 | 0.096 | 0.022 | 0.007 | 0.138 | #13 | 0.265 | Not Required | Pass |
| 115 | 0.000 | 0.052 | 0.057 | 0.016 | 0.005 | 0.102 | #13 | 0.321 | Not Required | Pass |
| 116 | 0.000 | 0.053 | 0.057 | 0.016 | 0.005 | 0.102 | #13 | 0.321 | Not Required | Pass |
| 201 | 0.024 | 0.488 | 0.001 | 0.031 | 0.000 | 0.501 | #13 | 0.485 | Not Required | Pass |
| 202 | 0.001 | 0.137 | 0.142 | 0.034 | 0.027 | 0.279 | #13 | 0.034 | Not Required | Pass |
| 203 | 0.006 | 0.290 | 0.045 | 0.029 | 0.008 | 0.331 | #13 | 0.044 | Not Required | Pass |
| 204 | 0.005 | 0.287 | 0.072 | 0.029 | 0.013 | 0.339 | #13 | 0.078 | Not Required | Pass |
| 205 | 0.005 | 0.179 | 0.074 | 0.029 | 0.015 | 0.195 | #13 | 0.073 | Not Required | Pass |
| 206 | 0.005 | 0.293 | 0.043 | 0.030 | 0.008 | 0.334 | #13 | 0.044 | Not Required | Pass |
| 207 | 0.005 | 0.181 | 0.076 | 0.029 | 0.014 | 0.195 | #13 | 0.073 | Not Required | Pass |
| 208 | 0.000 | 0.031 | 0.051 | 0.013 | 0.004 | 0.075 | #13 | Not Required | Not Required | Pass |
| 209 | 0.002 | 0.015 | 0.030 | 0.001 | 0.000 | 0.046 | #13 | 0.198 | Not Required | Pass |
| 210 | 0.005 | 0.292 | 0.075 | 0.029 | 0.013 | 0.340 | #13 | 0.078 | Not Required | Pass |
| 211 | 0.000 | 0.031 | 0.051 | 0.013 | 0.004 | 0.075 | #13 | Not Required | Not Required | Pass |
| 212 | 0.001 | 0.140 | 0.145 | 0.034 | 0.028 | 0.285 | #13 | 0.034 | Not Required | Pass |
| 213 | 0.002 | 0.084 | 0.110 | 0.023 | 0.007 | 0.174 | #13 | 0.177 | Not Required | Pass |
| 214 | 0.003 | 0.086 | 0.110 | 0.023 | 0.007 | 0.174 | #13 | 0.265 | Not Required | Pass |
| 215 | 0.000 | 0.051 | 0.057 | 0.017 | 0.005 | 0.100 | #13 | 0.321 | Not Required | Pass |
| 216 | 0.000 | 0.051 | 0.057 | 0.017 | 0.005 | 0.100 | #13 | 0.321 | 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 | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|--|---------------------------------------|---|---------------------------------------|---|---|-----------------------------|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|--------|--------|------------|--------|--------|------------|--------|--------|--|
| | <div><div>SkyCiv Foundation Design</div><div>Pile Foundation</div><div>Design Information :</div><div>Design code : IBC 2021 (International Building Code)</div><div>Unit System : Imperial</div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Pile Input</div><div></div><div>Geometry</div><div>Pile shape: rectangular</div><div>b = 48 in - Pile width</div><div>D = 48 in - Pile depth</div><div>L = 3.75 ft - Total pile length</div><div>h1 = 0 ft - Lateral load height from the top of the pile,</div><div>h2 = 0 ft - Depth to resisting surface</div><div>he = 0 ft - Length of pile above the ground</div><div>Tabulation of Soil Parameters</div><table><thead><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr></thead><tbody><tr><td>1</td><td>Sedimentary & foliated rock</td><td>4000.000</td><td>400.000</td></tr></tbody></table><div>Tabulation of Loads</div><table><thead><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr></thead><tbody><tr><td>P (kip)</td><td>2.196</td><td>3.088</td></tr><tr><td>Vx (kip)</td><td>-1.413</td><td>-2.353</td></tr><tr><td>Vz (kip)</td><td>-0.005</td><td>-0.008</td></tr><tr><td>Mx (kipft)</td><td>-0.010</td><td>-0.017</td></tr><tr><td>Mz (kipft)</td><td>12.283</td><td>20.642</td></tr></tbody></table><div>Material Properties</div><div>f'ck = 2.5 ksi - Concrete strength,</div></div> | Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | Load Component | ASD | LRFD | P (kip) | 2.196 | 3.088 | Vx (kip) | -1.413 | -2.353 | Vz (kip) | -0.005 | -0.008 | Mx (kipft) | -0.010 | -0.017 | Mz (kipft) | 12.283 | 20.642 | |
| Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 2.196 | 3.088 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vx (kip) | -1.413 | -2.353 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vz (kip) | -0.005 | -0.008 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mx (kipft) | -0.010 | -0.017 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mz (kipft) | 12.283 | 20.642 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Required depth to resist lateral loads (ASD)</div><div>H - Point of application of the lateral load</div><div><div><div><div>$H = h_1 + h_2 + h_e$</div><div>$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$</div><div>$H = 0 \text{ ft}$</div></div></div><div>Considering x-direction:</div><div>Ho - Lateral force per length of pile,</div><div><div><div>$H_o = \frac{V_x}{1.57 D}$</div><div>$H_o = \frac{(-1.413 \text{ kip})}{1.57 \times (48 \text{ in})}$</div><div>$H_o = -0.225 \text{ kip/ft}$</div></div></div></div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.283 \text{ kipft}) + ((-1.413 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9559 \text{ kipft/ft}$$

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:

$L_{e,x} = 3.4536 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.005 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.00079618 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.01 \text{ kipft}) + ((-0.005 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0015924 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.34613 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(3.4536 \text{ ft}), (0.34613 \text{ ft})]$$

$$L_{e,req} = 3.454 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (3.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 3.75 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(3.454 \text{ ft})}{(3.75 \text{ ft})}$$

$$\text{Ratio} = 0.92107$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(2.196 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.13725 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$Ratio = \frac{(0.13725 \text{ kip/ft}^2)}{(4000 \text{ psf})}$$

$$Ratio = 0.034313$$

Status: **PASS**
Ratio: **0.030**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 0.9375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.225 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.9559 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9559 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (1.9559 \text{ kipft/ft})) + (4 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.5698 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9559 \text{ kipft/ft})) + (3 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]^2}{(3.75 \text{ ft})^2 \times [(3 \times (1.9559 \text{ kipft/ft})) + (2 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]}$$

$$p = 0.35735 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.9559 \text{ kipft/ft})) + ((-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]}{(3.75 \text{ ft})^2}$$

$$s = 1.309 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400 \text{ psf/ft}) \times \frac{(2.5698 \text{ ft})}{2}$$

$$p_a = 0.51396 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

| | | |
|--|---|---|
| | $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.35735 \text{ kip/ft}^2)}{(0.51396 \text{ kip/ft}^2)}$ $Ratio = 0.69529$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (400 \text{ psf/ft}) \times (3.75 \text{ ft})$ $p_s = 1.5 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(1.309 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$ $Ratio = 0.87269$ | <p>Status: PASS Ratio: 0.700</p> <p>Status: PASS Ratio: 0.870</p> |
| | <p>Considering z-direction:</p> <p>$H_o = -0.00079618 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.0015924 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.0015924 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (0.0015924 \text{ kipft/ft})) + (4 \times (-0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))}$ $a = 2.6736 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.0015924 \text{ kipft/ft})) + (3 \times (-0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]^2}{(3.75 \text{ ft})^2 \times [(3 \times (0.0015924 \text{ kipft/ft})) + (2 \times (-0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]}$ $p = -0.00029901 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.0015924 \text{ kipft/ft})) + ((-0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]}{(3.75 \text{ ft})^2}$ $s = 0.000084926 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (400 \text{ psf/ft}) \times \frac{(2.6736 \text{ ft})}{2}$ $p_a = 0.53472 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(-0.00029901 \text{ kip/ft}^2)}{(0.53472 \text{ kip/ft}^2)}$ | |

$$Ratio = -0.00055919$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (400 \text{ psf/ft}) \times (3.75 \text{ ft})$$

$$p_s = 1.5 \text{ kip/ft}^2$$

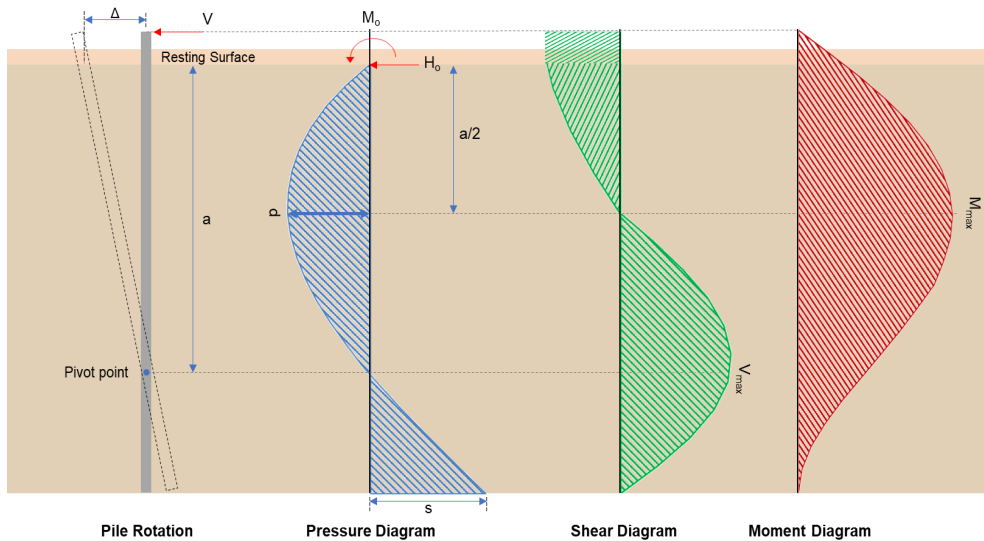
Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.000084926 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$$

$$Ratio = 0.000056617$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.353 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.37468 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.642 \text{ kipft}) + ((-2.353 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.2869 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.2869 \text{ kipft/ft})}{(-0.37468 \text{ kip/ft})}$$

$$E = 8.7726 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.2869 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (3.2869 \text{ kipft/ft})) + (4 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = \frac{(-0.37468 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (3.2869 \text{ kipft/ft})) + (4 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.5693 \text{ ft}$$

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

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

$$V_{max} = ((-0.37468 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.7726 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5693 \text{ ft})}{(3.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (8.7726 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5693 \text{ ft})}{(3.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1953 \text{ kip}$$

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

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

$$M_{max} = ((-0.37468 \text{ kip/ft}) \times (48 \text{ in}) \times (3.75 \text{ ft})) \times \left[\left(\frac{(8.7726 \text{ ft})}{(3.75 \text{ ft})} + \frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.7726 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.7726 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 12.979 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.008 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0012739 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.017 \text{ kipft}) + ((-0.008 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.002707 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.002707 \text{ kipft/ft})}{(-0.0012739 \text{ kip/ft})}$$

$$E = 2.125 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.002707 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.0012739 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (0.002707 \text{ kipft/ft})) + (4 \times (-0.0012739 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.6689 \text{ ft}$$

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

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

$$V_{max} = ((-0.0012739 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.6689 \text{ ft})}{(3.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.6689 \text{ ft})}{(3.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0084981 \text{ kip}$$

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

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

$$M_{max} = ((-0.0012739 \text{ kip/ft}) \times (48 \text{ in}) \times (3.75 \text{ ft})) \times \left[\left(\frac{(2.125 \text{ ft})}{(3.75 \text{ ft})} + \frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.014227 \text{ kipft}$$

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,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(3.088 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.494 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max [(-84.494 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | |
|---------------|--|
| <p>25.2.3</p> | <div> <div> $Ratio = 0.96556$ </div> </div> <p>s_{rebar} - Minimum spacing of reinforcement,</p> <div> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ </div> <p>Ties:</p> <p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p> <div> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ </div> <p>Summary:</p> <p>Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p> |
|---------------|--|

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

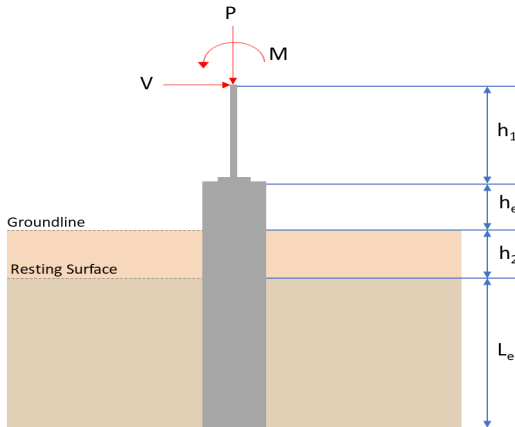
| | | | |
|---------------|--|--|--|
| | | $V_{c,max} = 296.21 \text{ kip}$ | |
| 22.5.5.1.1(a) | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 3.088 \text{ kip} \rightarrow 3088 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) | $V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(3088 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 118.9 \text{ kip}$ | |
| 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 | $V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (118.9 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 118.9 \text{ kip}$ | |
| 22.5.1.2 | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{s,a}$ - Shear strength of steel (a) | $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ | |
| | A_v - Ties rebar area, | $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ | |
| 22.5.8.5.3 | $V_{s,b}$ - Shear strength of steel (b) | $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ | |
| | V_s - Governing shear strength of steel | $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ | |
| 22.5.1.1 | ϕV_n - Allowable shear strength | $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((118.9 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.36 \text{ kip}$ | |
| | Considering x-direction: $V_{max} = 7.1953 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity | $Ratio = \frac{V_{max}}{\phi V_n}$ | |

| | | |
|-----------|---|--|
| | $Ratio = \frac{(7.1953 \text{ kip})}{(110.36 \text{ kip})}$ $Ratio = 0.065196$ <p>Considering z-direction:</p> <p>$V_{max} = 0.0084981 \text{ kip}$ - Maximum shear force in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.0084981 \text{ kip})}{(110.36 \text{ kip})}$ $Ratio = 0.000077$ <p>Status: PASS Ratio: 0.070</p> | |
| 14.5.2.1b | <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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction:</p> <p>$M_{max} = 12.979 \text{ kipft}$ - Maximum moment in the x-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(12.979 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.052$ <p>Status: PASS Ratio: 0.050</p> | |
| | <p>Considering z-direction:</p> <p>$M_{max} = 0.014227 \text{ kipft}$ - Maximum moment in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ | |

$$Ratio = \frac{(0.014227 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.000056997$$

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

| REFERENCES | CALCULATIONS | RESULTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|--|--|--|--|--|---|-----------------------------|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|-------|-------|------------|-------|-------|------------|--------|--------|--|
| | <div><div>SkyCiv Foundation Design</div><div>Pile Foundation</div><div>Design Information :</div><div>Design code : IBC 2021 (International Building Code)</div><div>Unit System : Imperial</div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Pile Input</div><div></div><div><div>Geometry</div><div>Pile shape: rectangular</div><div>b = 48 in - Pile width</div><div>D = 48 in - Pile depth</div><div>L = 3.75 ft - Total pile length</div><div>h1 = 0 ft - Lateral load height from the top of the pile,</div><div>h2 = 0 ft - Depth to resisting surface</div><div>he = 0 ft - Length of pile above the ground</div></div><div><div>Tabulation of Soil Parameters</div><table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sedimentary & foliated rock</td><td>4000.000</td><td>400.000</td></tr></table></div><div><div>Tabulation of Loads</div><table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>2.279</td><td>3.203</td></tr><tr><td>Vx (kip)</td><td>-1.443</td><td>-2.401</td></tr><tr><td>Vz (kip)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mx (kipft)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mz (kipft)</td><td>12.411</td><td>20.862</td></tr></table></div><div><div>Material Properties</div><div>f'ck = 2.5 ksi - Concrete strength,</div></div></div> | Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | Load Component | ASD | LRFD | P (kip) | 2.279 | 3.203 | Vx (kip) | -1.443 | -2.401 | Vz (kip) | 0.000 | 0.000 | Mx (kipft) | 0.000 | 0.000 | Mz (kipft) | 12.411 | 20.862 | |
| Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 2.279 | 3.203 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vx (kip) | -1.443 | -2.401 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vz (kip) | 0.000 | 0.000 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mx (kipft) | 0.000 | 0.000 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mz (kipft) | 12.411 | 20.862 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Required depth to resist lateral loads (ASD)</div><div>H - Point of application of the lateral load</div><div><div><div><div><div>$H = h_1 + h_2 + h_e$</div><div>$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$</div><div>$H = 0 \text{ ft}$</div></div></div></div></div><div><div>Considering x-direction:</div><div>Ho - Lateral force per length of pile,</div><div><div><div><div>$H_o = \frac{V_x}{1.57 D}$</div><div>$H_o = \frac{(-1.443 \text{ kip})}{1.57 \times (48 \text{ in})}$</div><div>$H_o = -0.22978 \text{ kip/ft}$</div></div></div></div></div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | |
|----------|---|--|
| | <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(12.411 \text{ kipft}) + ((-1.443 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 1.9763 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,x} = 3.4595 \text{ ft}$ - Required depth in x-direction,</p> <p>Considering z-direction: $L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction,</p> <p>Minimum embedded depth required: $L_{e,req}$ - Depth of pile required,</p> $L_{e,req} = MAX[L_{e,x}, L_{e,z}]$ $L_{e,req} = MAX[(3.4595 \text{ ft}), (0 \text{ ft})]$ $L_{e,req} = 3.459 \text{ ft}$ <p>L_e - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (3.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 3.75 \text{ ft}$ <p>Ratio - Embedded depth</p> $Ratio = \frac{L_{e,req}}{L_e}$ $Ratio = \frac{(3.459 \text{ ft})}{(3.75 \text{ ft})}$ $Ratio = 0.9224$ | <p>Status: PASS Ratio: 0.920</p> |
| | <p>End-bearing Capacity (ASD) A - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p>q - End-bearing pressure</p> $q = \frac{P_v}{A}$ $q = \frac{(2.279 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.14244 \text{ kip/ft}^2$ <p>Check bearing capacity ratio: Ratio - Capacity</p> $Ratio = \frac{q}{q_a}$ $Ratio = \frac{(0.14244 \text{ kip/ft}^2)}{(4000 \text{ psf})}$ $Ratio = 0.035609$ | <p>Status: PASS Ratio: 0.040</p> |
| Czerniak | <p>Lateral Soil Pressure (ASD): L/D - Length to least lateral dimension ratio,</p> | |

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

$$L/D = \frac{(3.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 0.9375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.22978 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.9763 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9763 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.22978 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (1.9763 \text{ kipft/ft})) + (4 \times (-0.22978 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.5704 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9763 \text{ kipft/ft})) + (3 \times (-0.22978 \text{ kip/ft}) \times (3.75 \text{ ft}))]^2}{(3.75 \text{ ft})^2 [(3 \times (1.9763 \text{ kipft/ft})) + (2 \times (-0.22978 \text{ kip/ft}) \times (3.75 \text{ ft}))]}$$

$$p = 0.35894 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.9763 \text{ kipft/ft})) + ((-0.22978 \text{ kip/ft}) \times (3.75 \text{ ft}))]}{(3.75 \text{ ft})^2}$$

$$s = 1.3188 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400 \text{ psf/ft}) \times \frac{(2.5704 \text{ ft})}{2}$$

$$p_a = 0.51408 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.35894 \text{ kip/ft}^2)}{(0.51408 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.69822$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (400 \text{ psf/ft}) \times (3.75 \text{ ft})$$

$$p_s = 1.5 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

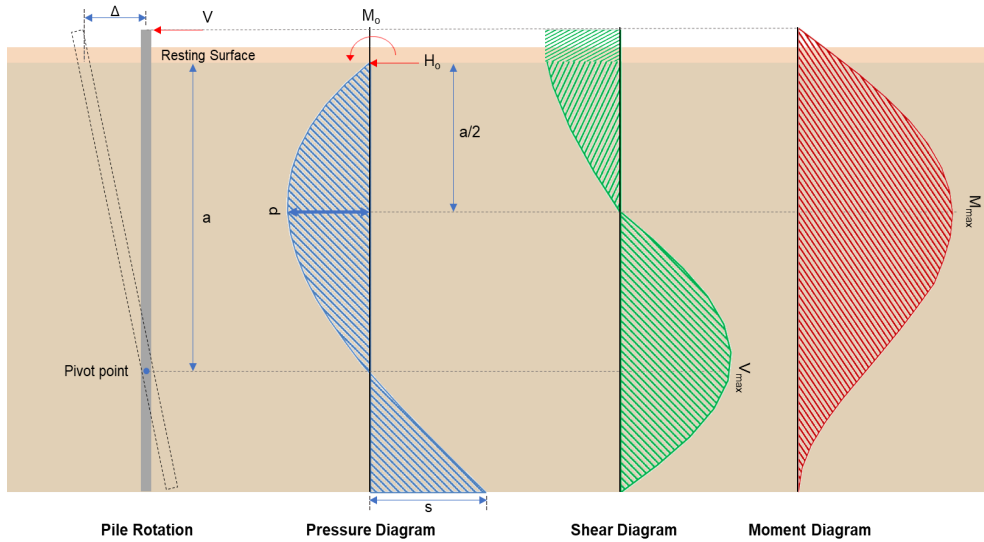
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(1.3188 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$$

Status: **PASS**
Ratio: **0.700**

$$Ratio = 0.87918$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.401 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.38232 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.862 \text{ kipft}) + ((-2.401 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.322 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.322 \text{ kipft/ft})}{(-0.38232 \text{ kip/ft})}$$

$$E = 8.6889 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.322 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.38232 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (3.322 \text{ kipft/ft})) + (4 \times (-0.38232 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.5698 \text{ ft}$$

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

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

$$V_{max} = ((-0.38232 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.6889 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5698 \text{ ft})}{(3.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (8.6889 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5698 \text{ ft})}{(3.75 \text{ ft})} \right)^3 \right] \right]$$

| | | |
|---|--|--|
| | $V_{max} = 1.2019 \text{ kip}$ <p>M_{max} - Max bending moment located at depth $a/2$,</p> $M_{max} = (H_o D L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2 L_e} \right) - \left[\left(\frac{4 E}{L_e} + 3 \right) \left(\frac{a}{2 L_e} \right)^3 + \left[\left(\frac{3 E}{L_e} + 2 \right) \left(\frac{a}{2 L_e} \right)^4 \right] \right] \right]$ $M_{max} = ((-0.38232 \text{ kip/ft}) \times (48 \text{ in}) \times (3.75 \text{ ft})) \times \left[\left(\frac{(8.6889 \text{ ft})}{(3.75 \text{ ft})} + \frac{(2.5698 \text{ ft})}{2 \times (3.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.6889 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5698 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (8.6889 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5698 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^4 \right] \right] \right]$ $M_{max} = 13.13 \text{ kipft}$ | |
| <p>Table 22.4.2.1</p> <p>22.4.2.2, 10.6.1.1</p> | <p>Minimum Reinforcement Check (LRFD)</p> <p>Parameters:</p> <p>$f'_{ck} = 2.5 \text{ ksi}$ - 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,</p> <p>Longitudinal reinforcement:</p> <p>Required reinforcement due to axial load, $A_{st,required}$</p> $A_{st,required} = \text{Min} \left[\frac{\frac{P}{\phi \alpha} - (0.85 f'_{ck} A_g)}{f_{yk} - (0.85 f'_{ck})}, (0.08 A_g) \right]$ $A_{st,required} = \text{Min} \left[\frac{\frac{(3.203 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$ $A_{st,required} = -84.49 \text{ in}^2$ <p>A_{min} - Governing minimum reinforcement area,</p> $A_{min} = \text{Max} [A_{st,required}, (0.0018 A_g)]$ $A_{min} = \text{Max} [(-84.49 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$ $A_{min} = 4.1472 \text{ in}^2$ <p>n_{rebar} - Required number of reinforcement,</p> $n_{rebar} = \frac{A_{min}}{A_{rebar}}$ $n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$ $n_{rebar} = 14$ <p>A_{st} - Actual total reinforcement area,</p> $A_{st} = n_{rebar} \frac{\pi d_{bar}^2}{4}$ $A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$ $A_{st} = 4.2951 \text{ in}^2$ <p>Ratio - Capacity</p> $\text{Ratio} = \frac{A_{min}}{A_{st}}$ $\text{Ratio} = \frac{(4.1472 \text{ in}^2)}{(4.2951 \text{ in}^2)}$ $\text{Ratio} = 0.96556$ <p>25.2.3 s_{rebar} - Minimum spacing of reinforcement,</p> $s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$ | <p>Status: PASS Ratio: 0.970</p> |

| | | |
|---------------|--|--|
| | <div><div>$s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]$$s_{rebar} = 1.5 \text{ in}$</div><div>Ties: Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $s_{ties} = Min [(16 d_{bar}), (48 d_{ties}), Min (D, b)]$$s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min ((48 \text{ in}), (48 \text{ in}))]$$s_{ties} = 10 \text{ in}$</div><div>Summary: Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</div></div> | |
| 22.4.2.2 | <div>Axial Compression Strength (ACI 318-19, LRFD) ϕP_N - Allowable axial compressive strength $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$$\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))]$$\phi P_N = 2675.2 \text{ kip}$ $Ratio$ - Capacity $Ratio = \frac{P}{\phi P_N}$$Ratio = \frac{(3.203 \text{ kip})}{(2675.2 \text{ kip})}$$Ratio = 0.0011973$</div> | Status: PASS Ratio: 0.000 |
| 22.5.2.2 | <div>Shear Strength (ACI 318-19, LRFD) Parameters: $b_w = 48 \text{ in}$ - Effective width, d - Effective depth $d = 0.80 D$$d = 0.80 \times (48 \text{ in})$$d = 38.4 \text{ in}$</div> | |
| 22.5.5.1.3 | <div>λ_s - size effect modification factor $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$$\lambda_s = 0.64282$</div> | |
| 22.5.5.1.1 | <div>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$$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}$</div> | |
| 22.5.5.1.1(a) | <div>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 3.203 \text{ kip} \rightarrow 3203 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$</div> | |

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(3203 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 118.91 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (118.91 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 118.91 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((118.91 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.37 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.2815 \text{ kip}$ - Maximum shear force in the x-direction,
 $Ratio$ - Capacity

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

$$Ratio = \frac{(7.2815 \text{ kip})}{(110.37 \text{ kip})}$$

$$Ratio = 0.065971$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

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

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

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:

$M_{max} = 13.13 \text{ kipft}$ - Maximum moment in the x-direction,

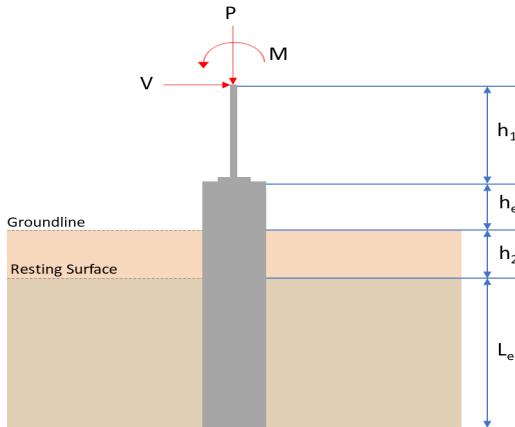
Ratio - Capacity

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

$$\text{Ratio} = \frac{(13.13 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.052605$$

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

| REFERENCES | CALCULATIONS | RESULTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|--|---------------------------------------|---|---------------------------------------|---|---|-----------------------------|----------|---------|----------------|-----|------|---------|-------|-------|----------|--------|--------|----------|-------|-------|------------|-------|-------|------------|--------|--------|--|
| | <div><div>SkyCiv Foundation Design</div><div>Pile Foundation</div><div>Design Information :</div><div>Design code : IBC 2021 (International Building Code)</div><div>Unit System : Imperial</div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Pile Input</div><div></div><div>Geometry</div><div>Pile shape: rectangular</div><div>b = 48 in - Pile width</div><div>D = 48 in - Pile depth</div><div>L = 3.75 ft - Total pile length</div><div>h1 = 0 ft - Lateral load height from the top of the pile,</div><div>h2 = 0 ft - Depth to resisting surface</div><div>he = 0 ft - Length of pile above the ground</div><div>Tabulation of Soil Parameters</div><table><thead><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr></thead><tbody><tr><td>1</td><td>Sedimentary & foliated rock</td><td>4000.000</td><td>400.000</td></tr></tbody></table><div>Tabulation of Loads</div><table><thead><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr></thead><tbody><tr><td>P (kip)</td><td>2.196</td><td>3.088</td></tr><tr><td>Vx (kip)</td><td>-1.413</td><td>-2.353</td></tr><tr><td>Vz (kip)</td><td>0.005</td><td>0.008</td></tr><tr><td>Mx (kipft)</td><td>0.010</td><td>0.017</td></tr><tr><td>Mz (kipft)</td><td>12.283</td><td>20.643</td></tr></tbody></table><div>Material Properties</div><div>f'ck = 2.5 ksi - Concrete strength,</div></div> | Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | Load Component | ASD | LRFD | P (kip) | 2.196 | 3.088 | Vx (kip) | -1.413 | -2.353 | Vz (kip) | 0.005 | 0.008 | Mx (kipft) | 0.010 | 0.017 | Mz (kipft) | 12.283 | 20.643 | |
| Layer | Label | Allowable Bearing Pressure (qa) (psf) | Allowable Lateral Pressure (R) (psf/ft) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | Sedimentary & foliated rock | 4000.000 | 400.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Load Component | ASD | LRFD | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P (kip) | 2.196 | 3.088 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vx (kip) | -1.413 | -2.353 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vz (kip) | 0.005 | 0.008 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mx (kipft) | 0.010 | 0.017 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mz (kipft) | 12.283 | 20.643 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>Required depth to resist lateral loads (ASD)</div><div>H - Point of application of the lateral load</div><div>H = h1 + h2 + he</div><div>H = (0 ft) + (0 ft) + (0 ft)</div><div>H = 0 ft</div><div>Considering x-direction:</div><div>Ho - Lateral force per length of pile,</div><div>Ho = Vx / 1.57 D</div><div>Ho = (-1.413 kip) / 1.57 x (48 in)</div><div>Ho = -0.225 kip/ft</div></div> | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | |
|--|---|---|
| | <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(12.283 \text{ kipft}) + ((-1.413 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 1.9559 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,x} = 3.4536 \text{ ft}$ - Required depth in x-direction,</p> <p>Considering z-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(0.005 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = 0.00079618 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.01 \text{ kipft}) + ((0.005 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.0015924 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,z} = 0.3792 \text{ ft}$ - Required depth in z-direction,</p> <p>Minimum embedded depth required:</p> <p>$L_{e,req}$ - Depth of pile required,</p> $L_{e,req} = MAX[L_{e,x}, L_{e,z}]$ $L_{e,req} = MAX[(3.4536 \text{ ft}), (0.3792 \text{ ft})]$ $L_{e,req} = 3.454 \text{ ft}$ <p>L_e - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (3.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 3.75 \text{ ft}$ <p>Ratio - Embedded depth</p> $Ratio = \frac{L_{e,req}}{L_e}$ $Ratio = \frac{(3.454 \text{ ft})}{(3.75 \text{ ft})}$ $Ratio = 0.92107$ | <p>Status: PASS Ratio: 0.920</p> |
| | <p>End-bearing Capacity (ASD)</p> <p>A - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p>q - End-bearing pressure</p> | |

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

$$q = \frac{(2.196 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.13725 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$Ratio = \frac{(0.13725 \text{ kip/ft}^2)}{(4000 \text{ psf})}$$

$$Ratio = 0.034313$$

Status: **PASS**
Ratio: **0.030**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 0.9375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.225 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.9559 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9559 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (1.9559 \text{ kipft/ft})) + (4 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.5698 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.9559 \text{ kipft/ft})) + (3 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]^2}{(3.75 \text{ ft})^2 \times [(3 \times (1.9559 \text{ kipft/ft})) + (2 \times (-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]}$$

$$p = 0.35735 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.9559 \text{ kipft/ft})) + ((-0.225 \text{ kip/ft}) \times (3.75 \text{ ft}))]}{(3.75 \text{ ft})^2}$$

$$s = 1.309 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400 \text{ psf/ft}) \times \frac{(2.5698 \text{ ft})}{2}$$

$$p_a = 0.51396 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

| | | |
|--|--|--|
| | $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.35735 \text{ kip/ft}^2)}{(0.51396 \text{ kip/ft}^2)}$ $Ratio = 0.69529$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (400 \text{ psf/ft}) \times (3.75 \text{ ft})$ $p_s = 1.5 \text{ kip/ft}^2$ <p>$Ratio$ - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(1.309 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$ $Ratio = 0.87269$ | <p>Status: PASS Ratio: 0.700</p> |
| | <p>Considering z-direction:</p> <p>$H_o = 0.00079618 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.0015924 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.0015924 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (0.0015924 \text{ kipft/ft})) + (4 \times (0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))}$ $a = 2.6736 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.0015924 \text{ kipft/ft})) + (3 \times (0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]^2}{(3.75 \text{ ft})^2 \times [(3 \times (0.0015924 \text{ kipft/ft})) + (2 \times (0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]}$ $p = 0.0011656 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.0015924 \text{ kipft/ft})) + ((0.00079618 \text{ kip/ft}) \times (3.75 \text{ ft}))]}{(3.75 \text{ ft})^2}$ $s = 0.0026327 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (400 \text{ psf/ft}) \times \frac{(2.6736 \text{ ft})}{2}$ $p_a = 0.53472 \text{ kip/ft}^2$ <p>$Ratio$ - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.0011656 \text{ kip/ft}^2)}{(0.53472 \text{ kip/ft}^2)}$ | <p>Status: PASS Ratio: 0.870</p> |

$$Ratio = 0.0021798$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (400 \text{ psf/ft}) \times (3.75 \text{ ft})$$

$$p_s = 1.5 \text{ kip/ft}^2$$

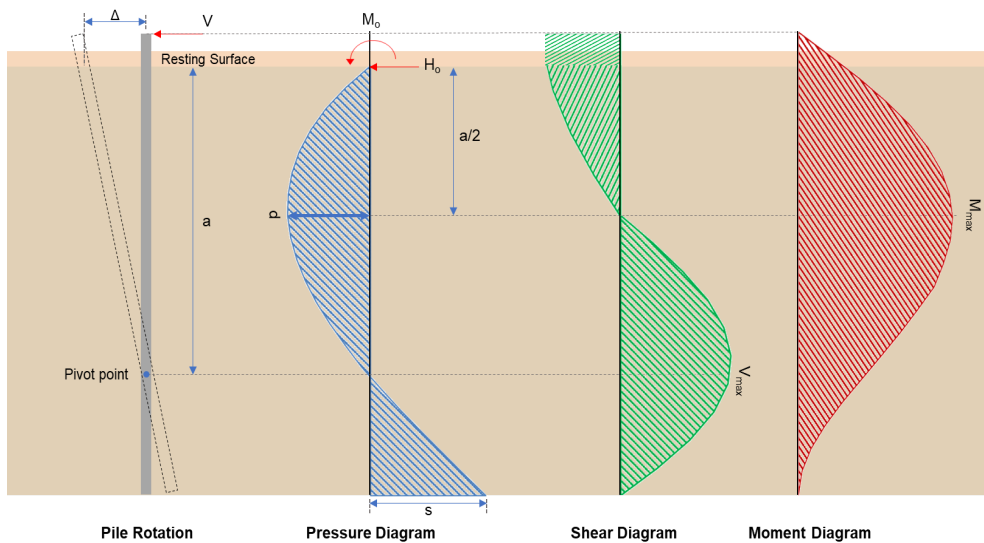
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0026327 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$$

$$Ratio = 0.0017551$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.353 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.37468 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(20.643 \text{ kipft}) + ((-2.353 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.2871 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.2871 \text{ kipft/ft})}{(-0.37468 \text{ kip/ft})}$$

$$E = 8.7731 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.2871 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (3.2871 \text{ kipft/ft})) + (4 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = \frac{(6 \times (3.2871 \text{ kipft/ft})) + (4 \times (-0.37468 \text{ kip/ft}) \times (3.75 \text{ ft}))}{}$$

$$a = 2.5693 \text{ ft}$$

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

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

$$V_{max} = ((-0.37468 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.7731 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5693 \text{ ft})}{(3.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (8.7731 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5693 \text{ ft})}{(3.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1956 \text{ kip}$$

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

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

$$M_{max} = ((-0.37468 \text{ kip/ft}) \times (48 \text{ in}) \times (3.75 \text{ ft})) \times \left[\left(\frac{(8.7731 \text{ ft})}{(3.75 \text{ ft})} + \frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.7731 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.7731 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.5693 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 12.98 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.008 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0012739 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.017 \text{ kipft}) + ((0.008 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.002707 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.002707 \text{ kipft/ft})}{(0.0012739 \text{ kip/ft})}$$

$$E = 2.125 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.002707 \text{ kipft/ft}) \times (3.75 \text{ ft})) + (3 \times (0.0012739 \text{ kip/ft}) \times (3.75 \text{ ft})^2)}{(6 \times (0.002707 \text{ kipft/ft})) + (4 \times (0.0012739 \text{ kip/ft}) \times (3.75 \text{ ft}))}$$

$$a = 2.6689 \text{ ft}$$

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

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

$$V_{max} = ((0.0012739 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.6689 \text{ ft})}{(3.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.6689 \text{ ft})}{(3.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0084981 \text{ kip}$$

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

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

$$M_{max} = ((0.0012739 \text{ kip/ft}) \times (48 \text{ in}) \times (3.75 \text{ ft})) \times \left[\left(\frac{(2.125 \text{ ft})}{(3.75 \text{ ft})} + \frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 3 \right) \times \left(\frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.125 \text{ ft})}{(3.75 \text{ ft})} + 2 \right) \times \left(\frac{(2.6689 \text{ ft})}{2 \times (3.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.014227 \text{ kipft}$$

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,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(3.088 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.494 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max [(-84.494 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | | |
|---|---|--|
| <p>25.2.3</p> | <p>$s_{rebar} = 0.96556$</p> <p>s_{rebar} - Minimum spacing of reinforcement,</p> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p>Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p> | <p>Status: PASS Ratio: 0.970</p> |
| <p>22.4.2.2</p> | <p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>$Ratio$ - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(3.088 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0011543$ | <p>Status: PASS Ratio: 0.000</p> |
| <p>22.5.2.2</p> <p>22.5.1.3</p> <p>22.5.1.1</p> | <p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ | |

| | | | |
|---------------|--|--|--|
| | | $V_{c,max} = 296.21 \text{ kip}$ | |
| 22.5.5.1.1(a) | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 3.088 \text{ kip} \rightarrow 3088 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) | $V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(3088 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 118.9 \text{ kip}$ | |
| 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 | $V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (118.9 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 118.9 \text{ kip}$ | |
| 22.5.1.2 | The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{s,a}$ - Shear strength of steel (a) | $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ | |
| | A_v - Ties rebar area, | $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ | |
| 22.5.8.5.3 | $V_{s,b}$ - Shear strength of steel (b) | $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ | |
| | V_s - Governing shear strength of steel | $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ | |
| 22.5.1.1 | ϕV_n - Allowable shear strength | $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((118.9 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.36 \text{ kip}$ | |
| | Considering x-direction: $V_{max} = 7.1956 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity | $Ratio = \frac{V_{max}}{\phi V_n}$ | |

| | | |
|-----------|---|--|
| | $Ratio = \frac{(7.1956 \text{ kip})}{(110.36 \text{ kip})}$ $Ratio = 0.065199$ <p>Considering z-direction:</p> <p>$V_{max} = 0.0084981 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.0084981 \text{ kip})}{(110.36 \text{ kip})}$ $Ratio = 0.000077$ <p>Status: PASS Ratio: 0.070</p> | |
| 14.5.2.1b | <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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction:</p> <p>$M_{max} = 12.98 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(12.98 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.052001$ <p>Status: PASS Ratio: 0.050</p> | |
| | <p>Considering z-direction:</p> <p>$M_{max} = 0.014227 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ | |

$$Ratio = \frac{(0.014227 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.000056997$$

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