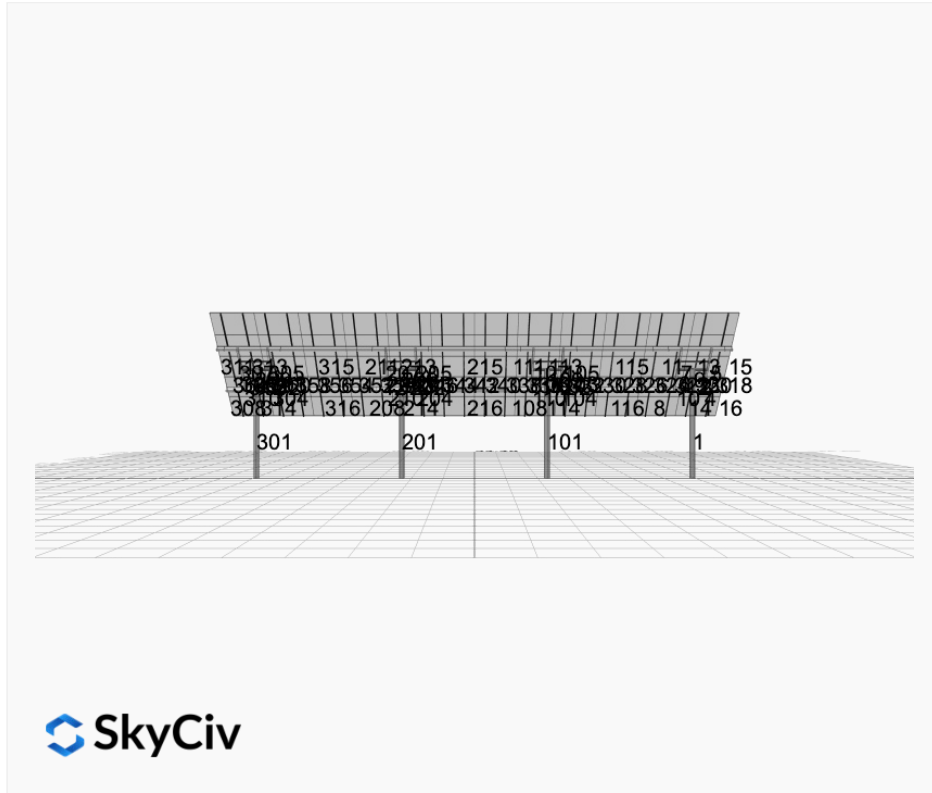


Project Name: Simpson Housing Carport 5x12 - V2Jb
Location: 19 Magnolia Way, Peabody, MA 01960, USA
Unique ID: 4P-19.75-8TOP-HD-12-L-5Hx12W-L584
Dealer: _____

Date: Fri Jul 11 2025
Number of Modules: 60
Number of Poles: 4
Date Sold: _____



| | |
|----------------------|----------|
| Array Dimensions N/S | 18.83 ft |
| Array Dimensions E/W | 68.80 ft |
| Winter Tilt Angle | 46 |
| Front Edge Clearance | 8 ft |

MT Solar Bill of Materials (4P-19.75-8TOP-HD-12-L-5Hx12W-L584)

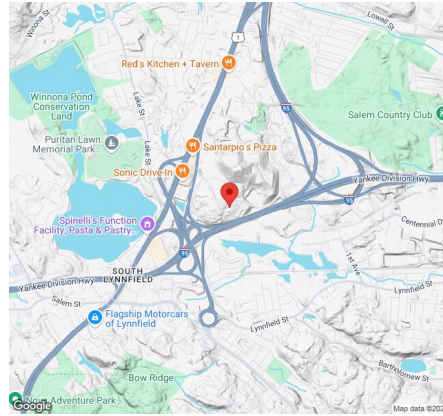
| Part | Short Description | BOM Qty |
|---------------------|-----------------------|---------|
| MTS-PC-8 | 8IN Pole Cap Assembly | 4 |
| MTS-HF-HD | H-Frame Assembly-HD | 4 |
| MTS-HD-Wing-12 | 12IN HD Wing | 4 |
| MTS-HD-Splice-90 | 90IN HD Splice | 6 |
| MTS-HD-Splice-57 | 57IN HD Splice | 6 |
| MTS-CLAMP-ANGLE-4PK | Angle Clamp | 12 |

Rail Bill of Materials

| Part | Qty |
|------------------|-----|
| Rails (226in) | 24 |
| Rail Attachment | 96 |
| Module Mid Clamp | 96 |
| Module End Clamp | 48 |

| Part | Qty |
|------------|-----|
| Ground Lug | 12 |

Site Details:



Site Address: 19 Magnolia Way, Peabody, MA 01960, USA

Array Specification

| | |
|------------------------------------|-----------|
| Duty Classification: | HD |
| Module Width: | 44.70 in |
| Module Length: | 67.80in |
| Number of Rows: | 5 |
| Number of Columns: | 12 |
| Total Number of Modules: | 60 |
| Winter Tilt Angle: | 46 |
| Front Edge Clearance: | 8 |
| Total Array Height at Tilt: | 21.55 ft |
| Total Frame Length: | 68.75 ft |
| Module Info/Notes: | 410w |
| Array Dimensions N/S: | 18.83 ft |
| Array Dimensions E/W: | 68.80 ft |
| Rail Length: | 226.00 in |
| Rail Spacing: | 2.87 ft |

Support Specifications

| | |
|---------------------------------|-----------------|
| Pole Size: | 8in Pipe Sch 40 |
| Pole Length above Grade: | 14.77 ft |
| Number of Poles: | 4 |
| Pole Spacing: | 19.75 ft |

Foundation Specifications

| | |
|--|--|
| Foundation Type: | Square |
| Foundation Dimensions: | 48 x 48 in |
| Foundation Depth (below grade): | Pile 1: 7.00 ft Pile 2: 7.50 ft Pile 3: 7.50 ft Pile 4: 7.00 ft |
| Foundation Volume: | 17.185 y ³ |

Site Info

| | |
|-----------------------------|---|
| Risk Category: | I |
| Exposure: | B |
| Soil Classification: | sand |
| Site Location: | 19 Magnolia Way, Peabody, MA 01960, USA |
| Wind Speed: | 109 mph |

Snow Load:

50 psf

Design Disclaimer

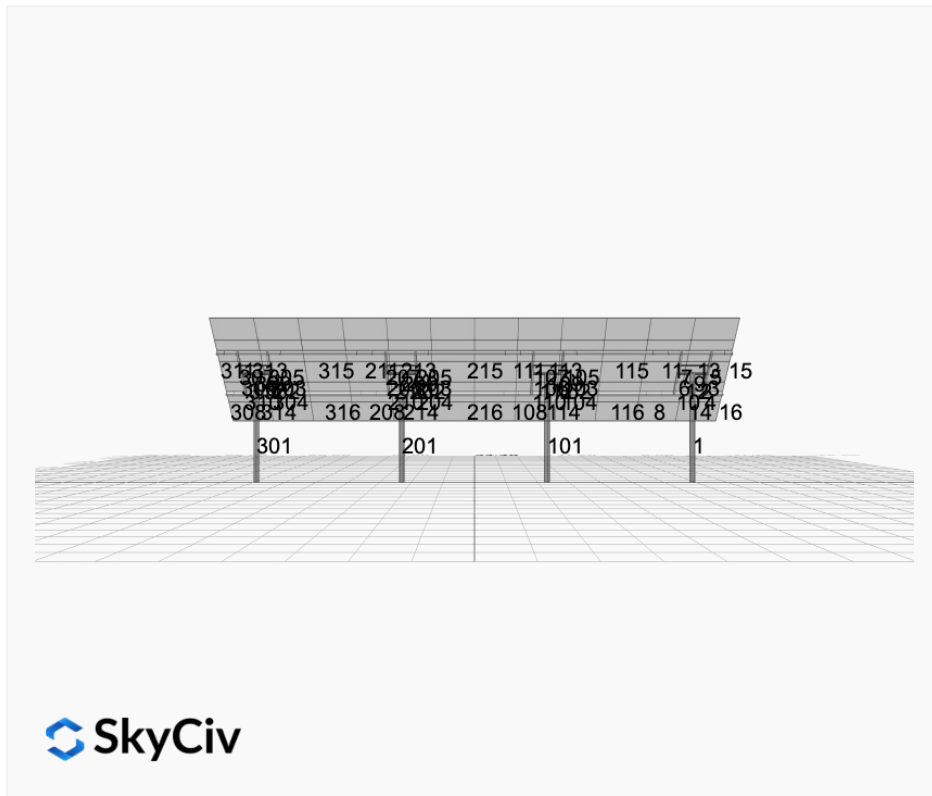
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

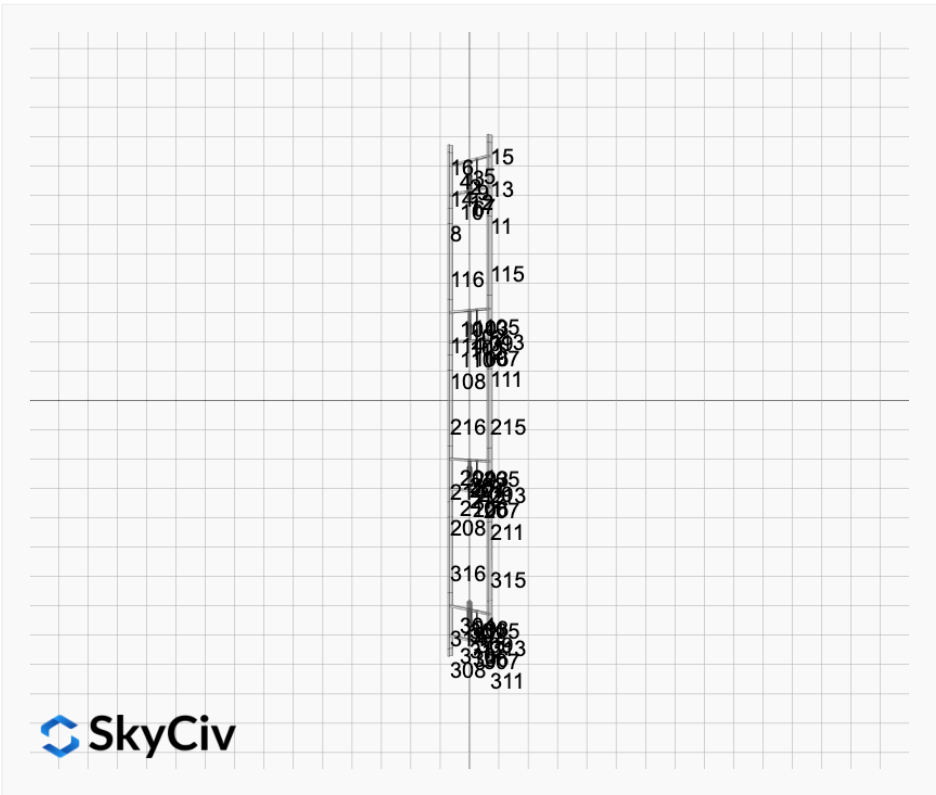
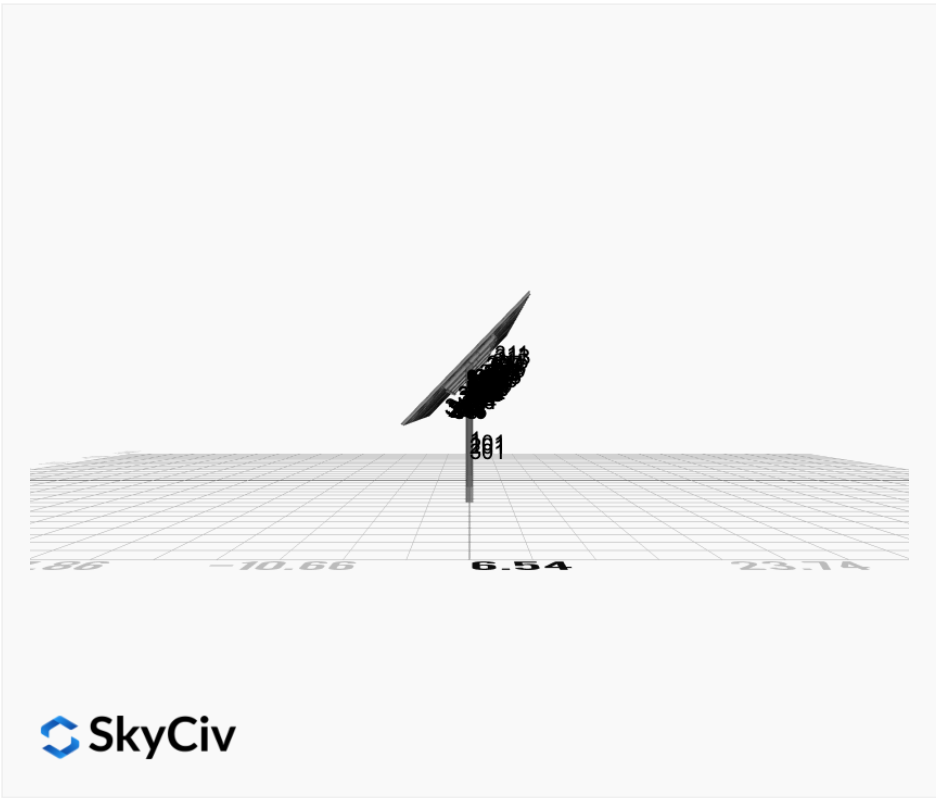
AutoDesigner Input

```
{ "wind_speed_override": null, "snow_load_override": null, "direct_snow_load": false, "add_angle_brace": false, "product_type": "Beam", "designer_name": "", "designer_email": "", "designer_phone": "", "project_id": "Simpson Housing Carport 5x12 - V2Jb", "site_address": "19 Magnolia Way, Peabody, MA 01960, USA", "module_info": "410w", "module_width": 44.7, "module_length": 67.8, "number_rows": 5, "number_columns": 12, "pole_mount_section": "4_40", "core_pipe_width": 65, "core_pipe_section": "2_40", "adjuster_section": "2_40", "core_beam_height": 65, "core_beam_section": "HSS3x2x1/8", "main_pipe_section": "2_12GA", "pole_spacing": "15", "tilt_angle": 46, "ground_clearance": 8, "risk_category": "I", "exposure_category": "B", "frame_duty_override": "auto", "pole_override": "auto", "soil_type": "sand", "customer_foundation_override": "48_Square", "foundation_type": "Square", "foundation_size": 48, "check_rails": true }
```

Design Notes:

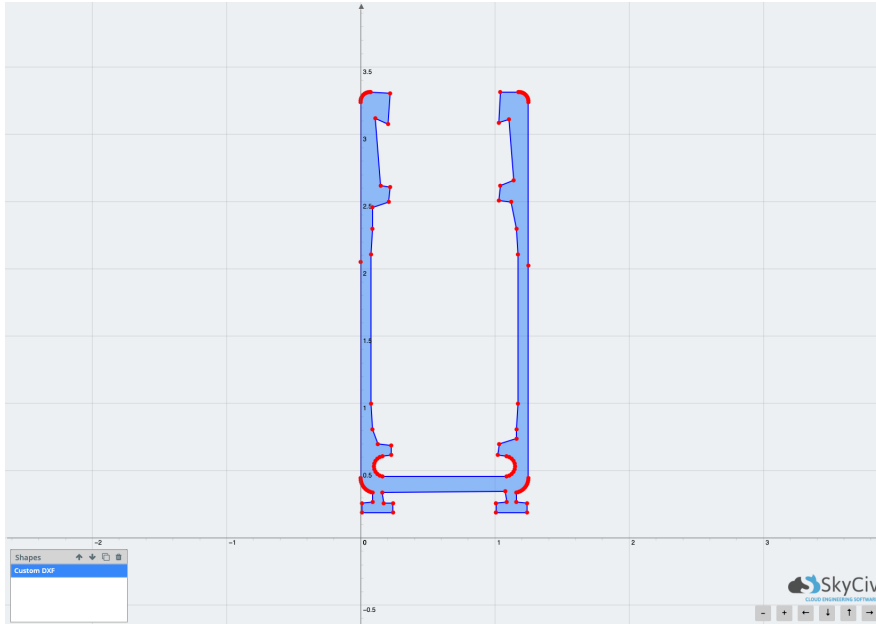
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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





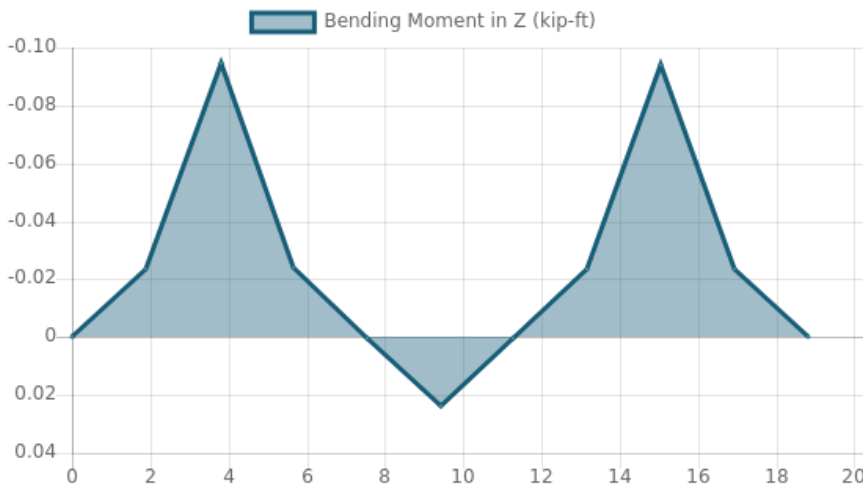
Rail Design Check

Rail Length: 18.833333333333332 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 2.866666666666667 ft
Material: Aluminium
Density: 169 lb/ft³
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0263 kip/ft
Snow (Y): -0.0272 kip/ft
Wind uplift Case A: 0.0498 kip/ft
Wind downforce Case A: 0.0498 kip/ft
Dead (Panel load) (X): 0.0091 kip/ft
Dead (Panel load) (Y): -0.0094 kip/ft

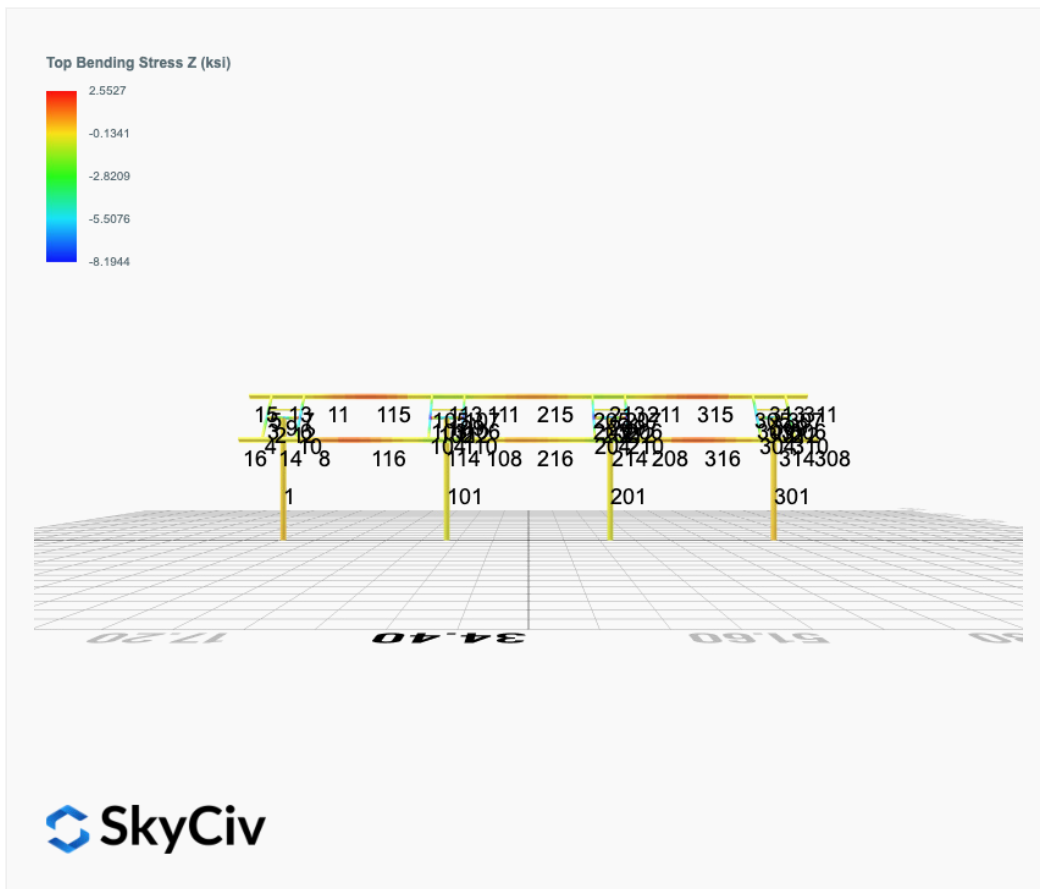
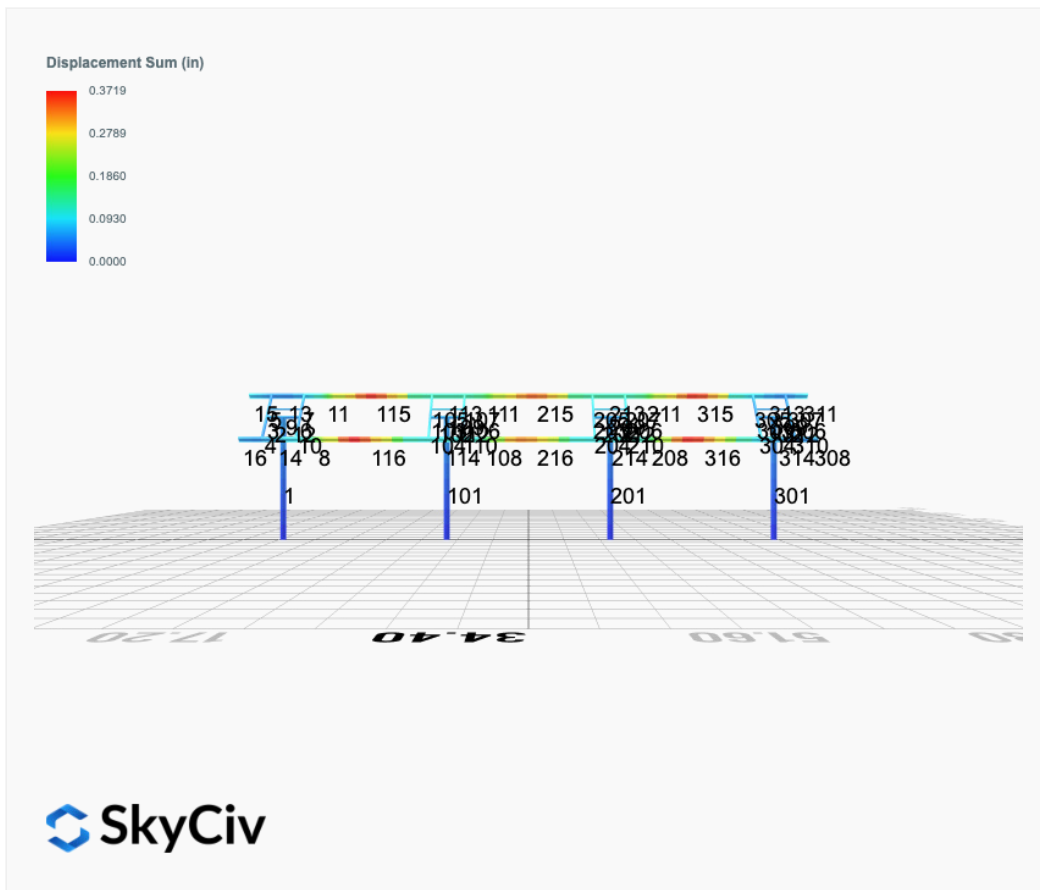


| Result Check | Max Limit | Max Value | Utility | Status |
|---------------------|-----------|------------|---------|--------|
| Custom Stress Limit | 34.5 | 12.4748765 | 0.362 | PASS |
| Material Yield | 34.5 | 12.4748765 | 0.362 | PASS |
| Material Strength | 37 | 12.4748765 | 0.337 | PASS |

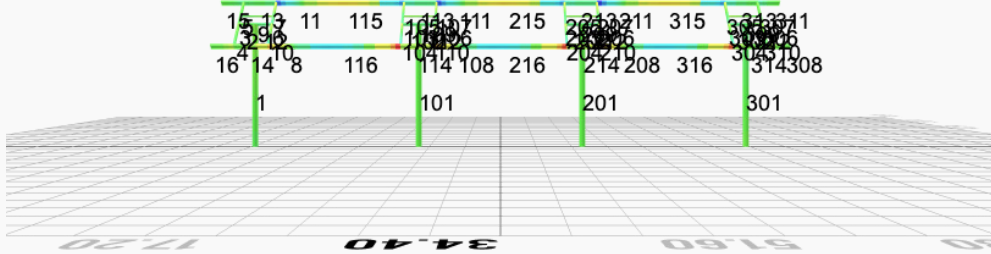
Member 1, ULS: 1. 1.4D



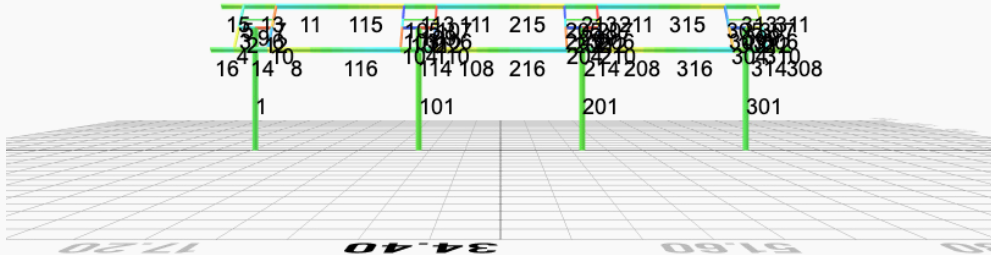
FEM Results (Envelope Worst Case for each member)



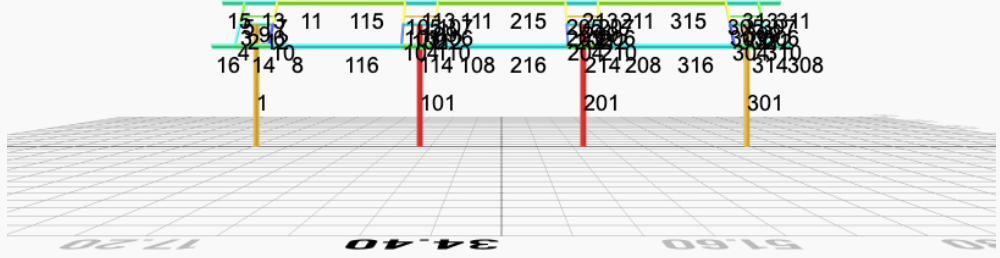
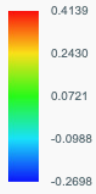
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (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 | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 2. D + L | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 3. D + (S or Lr or R) | 0.0853 | 4.6016 | 0.2247 | 1.0547 | -0.3640 | -1.1528 |
| ULS: 3. D + (S or Lr or R) | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0721 | 3.9871 | 0.1898 | 0.8911 | -0.3075 | -0.9713 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 5b. D + 0.7E | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0721 | 3.9871 | 0.1898 | 0.8911 | -0.3075 | -0.9713 |
| ULS: 8. 0.6D + 0.7E | 0.0195 | 1.2861 | 0.0512 | 0.2401 | -0.0827 | -0.2562 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.0597 | 4.0689 | 0.3290 | 1.5082 | -1.3350 | 31.3538 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.1150 | 0.2233 | -0.1499 | -0.6666 | 1.0175 | -31.0281 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.4970 | 5.4311 | 0.3726 | 1.7221 | -1.2053 | 22.8643 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0721 | 3.9871 | 0.1898 | 0.8911 | -0.3075 | -0.9713 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6340 | 2.5469 | 0.0134 | 0.0910 | 0.5590 | -23.9221 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0721 | 3.9871 | 0.1898 | 0.8911 | -0.3075 | -0.9713 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5367 | 3.5875 | 0.2681 | 1.2312 | -1.0358 | 23.4086 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.5944 | 0.7033 | -0.0911 | -0.3999 | 0.7286 | -23.3778 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0325 | 2.1435 | 0.0853 | 0.4001 | -0.1379 | -0.4270 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.0727 | 3.2115 | 0.2949 | 1.3481 | -1.2799 | 31.5246 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0195 | 1.2861 | 0.0512 | 0.2401 | -0.0827 | -0.2562 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.1020 | -0.6341 | -0.1841 | -0.8267 | 1.0726 | -30.8573 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0195 | 1.2861 | 0.0512 | 0.2401 | -0.0827 | -0.2562 |

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundation Module.

Note: Worst case values are assumed as downforce wind load cases.

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 8.1123 |
| Shear X | -3.5445 |
| Shear Z | 0.5863 |
| Moment X | 2.6947 |
| Moment Y (Twist) | 2.3130 |
| Moment Z | 53.3430 |

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.

Note: Worst case values are assumed as downforce wind load cases.

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 5.4311 |
| Shear X | -2.1150 |
| Shear Z | 0.3726 |
| Moment X | 1.7221 |
| Moment Y (Twist) | 1.3350 |
| Moment Z | 31.5246 |

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 | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 2. D + L | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 3. D + (S or Lr or R) | -0.0853 | 6.2447 | -0.0041 | -0.0211 | 0.0081 | 1.2283 |
| ULS: 3. D + (S or Lr or R) | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0721 | 5.3757 | -0.0035 | -0.0179 | 0.0069 | 1.0398 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---------|---------|---------|---------|---------|----------|
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 5b. D + 0.7E | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0721 | 5.3757 | -0.0035 | -0.0179 | 0.0069 | 1.0398 |
| ULS: 8. 0.6D + 0.7E | -0.0195 | 1.6611 | -0.0010 | -0.0049 | 0.0020 | 0.2846 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.7946 | 5.5309 | 0.0435 | 0.1939 | -0.2763 | 41.8734 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.7393 | 0.0010 | -0.0415 | -0.1862 | 0.2554 | -39.2469 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.1437 | 7.4475 | 0.0304 | 0.1337 | -0.2028 | 32.0891 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0721 | 5.3757 | -0.0035 | -0.0179 | 0.0069 | 1.0398 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0067 | 3.3000 | -0.0334 | -0.1514 | 0.1960 | -28.7511 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0721 | 5.3757 | -0.0035 | -0.0179 | 0.0069 | 1.0398 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.1041 | 4.8403 | 0.0322 | 0.1434 | -0.2064 | 31.5236 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0464 | 0.6929 | -0.0315 | -0.1417 | 0.1924 | -29.3166 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0325 | 2.7685 | -0.0016 | -0.0082 | 0.0033 | 0.4743 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.7816 | 4.4235 | 0.0441 | 0.1972 | -0.2776 | 41.6836 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0195 | 1.6611 | -0.0010 | -0.0049 | 0.0020 | 0.2846 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.7523 | -1.1065 | -0.0409 | -0.1830 | 0.2541 | -39.4366 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0195 | 1.6611 | -0.0010 | -0.0049 | 0.0020 | 0.2846 |

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 | 11.1835 |
| Shear X | -4.6591 |
| Shear Z | 0.0772 |
| Moment X | 0.3444 |
| Moment Y (Twist) | 0.4880 |
| Moment Z | 71.7205 |

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 | 7.4475 |
| Shear X | -2.7946 |
| Shear Z | 0.0441 |
| Moment X | 0.1972 |
| Moment Y (Twist) | 0.2776 |
| Moment Z | 41.8734 |

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 | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 2. D + L | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 3. D + (S or Lr or R) | -0.0853 | 6.2447 | 0.0041 | 0.0210 | -0.0080 | 1.2283 |
| ULS: 3. D + (S or Lr or R) | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0721 | 5.3757 | 0.0035 | 0.0178 | -0.0068 | 1.0398 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 5b. D + 0.7E | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | -0.0721 | 5.3757 | 0.0035 | 0.0178 | -0.0068 | 1.0398 |
| ULS: 8. 0.6D + 0.7E | -0.0195 | 1.6611 | 0.0010 | 0.0049 | -0.0019 | 0.2846 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.7946 | 5.5309 | -0.0435 | -0.1939 | 0.2764 | 41.8734 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.7393 | 0.0010 | 0.0415 | 0.1862 | -0.2554 | -39.2469 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |

| 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 | -2.1437 | 7.4475 | -0.0304 | -0.1337 | 0.2029 | 32.0891 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0721 | 5.3757 | 0.0035 | 0.0178 | -0.0068 | 1.0398 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0067 | 3.3000 | 0.0334 | 0.1514 | -0.1959 | -28.7511 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0721 | 5.3757 | 0.0035 | 0.0178 | -0.0068 | 1.0398 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -2.1041 | 4.8403 | -0.0322 | -0.1434 | 0.2065 | 31.5236 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 2.0464 | 0.6929 | 0.0315 | 0.1417 | -0.1923 | -29.3166 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | -0.0325 | 2.7685 | 0.0016 | 0.0082 | -0.0032 | 0.4743 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.7816 | 4.4235 | -0.0441 | -0.1972 | 0.2777 | 41.6836 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | -0.0195 | 1.6611 | 0.0010 | 0.0049 | -0.0019 | 0.2846 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.7523 | -1.1065 | 0.0409 | 0.1830 | -0.2541 | -39.4366 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | -0.0195 | 1.6611 | 0.0010 | 0.0049 | -0.0019 | 0.2846 |

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 | 11.1835 |
| Shear X | -4.6591 |
| Shear Z | -0.0772 |
| Moment X | -0.3451 |
| Moment Y (Twist) | 0.4883 |
| Moment Z | 71.7209 |

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 | 7.4475 |
| Shear X | -2.7946 |
| Shear Z | -0.0441 |
| Moment X | -0.1972 |
| Moment Y (Twist) | 0.2777 |
| Moment Z | 41.8734 |

Reaction Forces for Foundation 4 (Node ID#301), (kip, kip-ft)

ASD Load Combination Results

| Name | Fx | Fy | Fz | Mx | My | Mz |
|---|---------|--------|---------|---------|---------|----------|
| ULS: 1. D | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 2. D + L | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 3. D + (S or Lr or R) | 0.0853 | 4.6016 | -0.2247 | -1.0549 | 0.3641 | -1.1527 |
| ULS: 3. D + (S or Lr or R) | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0721 | 3.9871 | -0.1898 | -0.8912 | 0.3076 | -0.9712 |
| ULS: 4. D + 0.75L + 0.75(S or Lr or R) | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 5b. D + 0.7E | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S | 0.0721 | 3.9871 | -0.1898 | -0.8912 | 0.3076 | -0.9712 |
| ULS: 8. 0.6D + 0.7E | 0.0195 | 1.2861 | -0.0512 | -0.2401 | 0.0827 | -0.2562 |
| ULS: 5a. D + 0.6W_Wind downforce Case A only | -2.0597 | 4.0689 | -0.3290 | -1.5082 | 1.3351 | 31.3538 |
| ULS: 5a. D + 0.6W_Wind downforce Case B only | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 5a. D + 0.6W_Wind uplift Case A only | 2.1150 | 0.2233 | 0.1499 | 0.6666 | -1.0174 | -31.0281 |
| ULS: 5a. D + 0.6W_Wind uplift Case B only | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.4970 | 5.4311 | -0.3726 | -1.7222 | 1.2054 | 22.8644 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0721 | 3.9871 | -0.1898 | -0.8912 | 0.3076 | -0.9712 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.6340 | 2.5469 | -0.0134 | -0.0912 | -0.5589 | -23.9221 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0721 | 3.9871 | -0.1898 | -0.8912 | 0.3076 | -0.9712 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only | -1.5367 | 3.5875 | -0.2681 | -1.2312 | 1.0358 | 23.4086 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only | 1.5944 | 0.7033 | 0.0911 | 0.3999 | -0.7286 | -23.3778 |
| ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only | 0.0325 | 2.1435 | -0.0853 | -0.4002 | 0.1379 | -0.4270 |

| Name | Fx | Fy | Fz | Mx | My | Mz |
|--|---------|---------|---------|---------|---------|----------|
| ULS: 7. 0.6D + 0.6W_Wind downforce Case A only | -2.0727 | 3.2115 | -0.2949 | -1.3481 | 1.2799 | 31.5246 |
| ULS: 7. 0.6D + 0.6W_Wind downforce Case B only | 0.0195 | 1.2861 | -0.0512 | -0.2401 | 0.0827 | -0.2562 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case A only | 2.1020 | -0.6341 | 0.1841 | 0.8266 | -1.0726 | -30.8573 |
| ULS: 7. 0.6D + 0.6W_Wind uplift Case B only | 0.0195 | 1.2861 | -0.0512 | -0.2401 | 0.0827 | -0.2562 |

Worst Case Reactions LRFD

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

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 8.1122 |
| Shear X | -3.5445 |
| Shear Z | -0.5863 |
| Moment X | -2.6953 |
| Moment Y (Twist) | 2.3133 |
| Moment Z | 53.3442 |

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.
 Note: Worst case values are assumed as downforce wind load cases.

| Result | Value (kip, kip-ft) |
|------------------|---------------------|
| Axial | 5.4311 |
| Shear X | -2.1150 |
| Shear Z | -0.3726 |
| Moment X | -1.7222 |
| Moment Y (Twist) | 1.3351 |
| Moment Z | 31.5246 |

Project Details

Design Code: AISC 360-16 LRFD
 Provision: LRFD
 Country: United States

 User Name: sales@mtsolar.us
 Project Name: Simpson Housing Carport 5x12 - V2Jb
 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) | | | | |
|----|-----------------|--------|------------|--|--|--|--|
| 2 | 2in Pipe Sch 80 | 2.38 | 0.22 | | | | |
| 5 | 4in Pipe Sch 80 | 4.50 | 0.34 | | | | |
| 9 | 8in Pipe Sch 40 | 8.63 | 0.32 | | | | |

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

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

| Section Properties | | | | | | | | |
|--------------------|------|----------------------|----------------------|-----------------------------|-----------------------------|--------------------------|-----------------------------|-----------------------------|
| ID | Name | A (in ²) | J (in ⁴) | I_{y0} (in ⁴) | I_{z0} (in ⁴) | I_w (in ⁶) | S_{y0} (in ³) | S_{z0} (in ³) |

| | | | | | | | | |
|-----|----|-------|-------|-------|--|-----|-----|---|
| 113 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.13,1.07,2.76,1.07,1.14,1.07,1.34,1.07,1.10,1.07,1.02,1.07,1.12,1.07,3.76,1.07,1.15,1.07,1.20,1.07 | 300 | 200 | 1 |
| 114 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.06,1.14,1.06,1.09,1.06,1.11,1.06,1.08,1.06,1.03,1.06,1.09,1.06,1.16,1.06,1.09,1.06,1.11,1.06 | 300 | 200 | 1 |
| 115 | 19 | 6.63 | 6.63 | 10.20 | 1.14,1.14,1.14,1.14,1.14,1.14,1.09,1.14,1.06,1.14,1.08,1.14,1.07,1.14,1.11,1.14,1.33,1.14,1.09,1.14,1.06,1.14,1.08,1.14,1.07,1.14 | 300 | 200 | 1 |
| 116 | 19 | 6.63 | 6.63 | 10.20 | 1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.12,1.15,1.13,1.15,1.13,1.15,1.14,1.15,1.20,1.15,1.14,1.15,1.11,1.15,1.13,1.15,1.13,1.15 | 300 | 200 | 1 |
| 201 | 9 | 31.02 | 31.02 | 14.77 | - | 300 | 200 | 1 |
| 202 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 203 | 16 | 0.92 | 0.92 | 1.42 | 1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.11,7,1.19,1.18,1.19,1.18,1.19 | 300 | 200 | 1 |
| 204 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.66,5,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 205 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,6,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 206 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.11,6,1.18,1.18,1.18,1.17,1.18 | 300 | 200 | 1 |
| 207 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.66,5,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 208 | 19 | 1.33 | 1.33 | 2.05 | 1.93,1.94,1.93,1.94,1.94,1.93,1.68,1.94,1.48,1.94,1.66,1.93,1.56,1.93,1.78,1.94,2.17,1.94,1.70,1.93,1.44,1.93,1.65,1.93,1.58,1.93 | 300 | 200 | 1 |
| 209 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 210 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,5,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 211 | 19 | 1.33 | 1.33 | 2.05 | 1.69,1.69,1.69,1.68,1.69,1.69,1.34,1.69,1.17,1.69,1.31,1.69,1.22,1.69,1.44,1.68,1.96,1.68,1.36,1.69,1.11,3,1.69,1.30,1.69,1.24,1.69 | 300 | 200 | 1 |
| 212 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 213 | 19 | 4.88 | 4.00 | 7.50 | 1.07,1.07,1.07,1.07,1.07,1.07,1.13,1.07,2.76,1.07,1.14,1.07,1.34,1.07,1.10,1.07,1.02,1.07,1.12,1.07,3.76,1.07,1.15,1.07,1.20,1.07 | 300 | 200 | 1 |
| 214 | 19 | 4.88 | 4.00 | 7.50 | 1.06,1.06,1.06,1.06,1.06,1.06,1.09,1.06,1.13,1.06,1.09,1.06,1.11,1.06,1.08,1.06,1.03,1.06,1.09,1.06,1.16,1.06,1.09,1.06,1.11,1.06 | 300 | 200 | 1 |
| 215 | 19 | 6.63 | 6.63 | 10.20 | 1.15,1.15,1.15,1.15,1.15,1.15,1.11,1.15,1.08,1.15,1.11,1.15,1.09,1.15,1.13,1.15,2.38,1.15,1.11,1.15,1.07,1.15,1.11,1.15,1.09,1.15 | 300 | 200 | 1 |
| 216 | 19 | 6.63 | 6.63 | 10.20 | 1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.12,1.17,1.14,1.17,1.13,1.17,1.16,1.17,1.24,1.17,1.15,1.17,1.11,2,1.17,1.14,1.17,1.14,1.17 | 300 | 200 | 1 |
| 301 | 9 | 31.02 | 31.02 | 14.77 | - | 300 | 200 | 1 |
| 302 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 303 | 16 | 0.92 | 0.92 | 1.42 | 1.19,8,1.19,1.19,1.19,1.19 | 300 | 200 | 1 |
| 304 | 16 | 2.44 | 2.44 | 3.75 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,5,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 305 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.68,1.66,6,1.68,1.67,1.68,1.67,1.68 | 300 | 200 | 1 |
| 306 | 16 | 0.92 | 0.92 | 1.42 | 1.18,1.18,1.18,1.17,1.18,1.18,1.16,1.18,1.14,1.18,1.16,1.18,1.15,1.18,1.17,1.17,1.19,1.17,1.17,1.18,1.11,2,1.18,1.16,1.18,1.15,1.18 | 300 | 200 | 1 |
| 307 | 16 | 1.52 | 1.52 | 2.33 | 1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,4,1.68,1.67,1.68,1.66,1.68 | 300 | 200 | 1 |
| 308 | 19 | 2.10 | 2.10 | 1.00 | 2.33,3,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 309 | 2 | 2.60 | 2.60 | 4.00 | - | 300 | 200 | 1 |
| 310 | 16 | 2.44 | 2.44 | 3.75 | 1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.69,1.68,1.68,1.69,1.66,3,1.69,1.67,1.69,1.66,1.69 | 300 | 200 | 1 |
| 311 | 19 | 2.10 | 2.10 | 1.00 | 2.33,3,2.33,2.33,2.33,2.33 | 300 | 200 | 1 |
| 312 | 5 | 1.30 | 1.30 | 2.00 | - | 300 | 200 | 1 |
| 313 | 19 | 4.88 | 4.00 | 7.50 | 1.25,1.25,1.25,1.25,1.25,1.25,1.21,1.25,1.36,1.25,1.23,1.25,1.30,1.25,1.17,1.25,2.90,1.25,1.19,1.25,1.40,1.25,1.23,1.25,1.29,1.25 | 300 | 200 | 1 |
| 314 | 19 | 4.88 | 4.00 | 7.50 | 1.38,1.40,1.38,1.41,1.39,1.38,1.39,1.40,1.39,1.40,1.38,1.38,1.39,1.38,1.40,1.41,1.43,1.41,1.39,1.38,1.3 | 300 | 200 | 1 |

| | | | | | | | | |
|-----|----|------|------|-------|---|------|------|---|
| 314 | 19 | 4.88 | 4.00 | 0 | 9,1.38,1.38,1.38,1.39,1.38 | 0 | 0 | 1 |
| 315 | 19 | 6.63 | 6.63 | 10.20 | 1.08,1.08,1.08,1.08,1.08,1.08,1.10,1.08,1.14,1.08,1.10,1.08,1.12,1.08,1.09,1.08,1.10,1.08,1.10,1.08,1.16,1.08,1.10,1.08,1.11,1.08 | 30.0 | 20.0 | 1 |
| 316 | 19 | 6.63 | 6.63 | 10.20 | 1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.07,1.08,1.08,1.07,1.08 | 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 | 377.97 | 118.15 | 83.29 | 83.29 | 113.39 | 113.39 |
| 2 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 3 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 4 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 5 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 6 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 7 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 8 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 9 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 10 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 11 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 12 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 13 | 133.20 | 85.85 | 26.92 | 6.12 | 40.24 | 43.62 |
| 14 | 133.20 | 85.85 | 31.67 | 6.12 | 40.24 | 43.62 |
| 15 | 133.20 | 121.82 | 32.87 | 6.12 | 40.24 | 43.62 |
| 16 | 133.20 | 121.82 | 32.87 | 6.12 | 40.24 | 43.62 |
| 101 | 377.97 | 118.15 | 83.29 | 83.29 | 113.39 | 113.39 |
| 102 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 103 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 104 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 105 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 106 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 107 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 108 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 109 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 110 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 111 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 112 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 113 | 133.20 | 85.85 | 23.47 | 6.12 | 40.24 | 43.62 |
| 114 | 133.20 | 85.85 | 23.66 | 6.12 | 40.24 | 43.62 |
| 115 | 133.20 | 69.16 | 16.43 | 6.12 | 40.24 | 43.62 |
| 116 | 133.20 | 69.16 | 17.20 | 6.12 | 40.24 | 43.62 |
| 201 | 377.97 | 118.15 | 83.29 | 83.29 | 113.39 | 113.39 |
| 202 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 203 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 204 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 205 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 206 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 207 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 208 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |
| 209 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 210 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 211 | 133.20 | 123.95 | 32.87 | 6.12 | 40.24 | 43.62 |

| | | | | | | |
|-----|--------|--------|-------|-------|--------|--------|
| 212 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 213 | 133.20 | 85.85 | 23.46 | 6.12 | 40.24 | 43.62 |
| 214 | 133.20 | 85.85 | 23.65 | 6.12 | 40.24 | 43.62 |
| 215 | 133.20 | 69.16 | 16.61 | 6.12 | 40.24 | 43.62 |
| 216 | 133.20 | 69.16 | 17.29 | 6.12 | 40.24 | 43.62 |
| 301 | 377.97 | 118.15 | 83.29 | 83.29 | 113.39 | 113.39 |
| 302 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 303 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 304 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 305 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 306 | 116.10 | 115.41 | 15.79 | 11.10 | 42.08 | 23.28 |
| 307 | 116.10 | 114.23 | 15.79 | 11.10 | 42.08 | 23.28 |
| 308 | 133.20 | 121.82 | 32.87 | 6.12 | 40.24 | 43.62 |
| 309 | 66.48 | 58.89 | 3.82 | 3.82 | 19.94 | 19.94 |
| 310 | 116.10 | 111.33 | 15.79 | 11.10 | 42.08 | 23.28 |
| 311 | 133.20 | 121.82 | 32.87 | 6.12 | 40.24 | 43.62 |
| 312 | 198.33 | 196.72 | 21.95 | 21.95 | 59.50 | 59.50 |
| 313 | 133.20 | 85.85 | 26.92 | 6.12 | 40.24 | 43.62 |
| 314 | 133.20 | 85.85 | 31.71 | 6.12 | 40.24 | 43.62 |
| 315 | 133.20 | 69.16 | 16.70 | 6.12 | 40.24 | 43.62 |
| 316 | 133.20 | 69.16 | 16.57 | 6.12 | 40.24 | 43.62 |

Design Ratio

| Member ID | P | M _z | M _y | V _y | V _z | (P,M _z ,M _y) | Worst LC | KL/r | δ | Status |
|-----------|-------|----------------|----------------|----------------|----------------|-------------------------------------|----------|--------------|--------------|--------|
| 1 | 0.069 | 0.640 | 0.072 | 0.031 | 0.005 | 0.703 | #13 | 0.634 | Not Required | Pass |
| 2 | 0.002 | 0.141 | 0.101 | 0.040 | 0.022 | 0.205 | #21 | 0.053 | Not Required | Pass |
| 3 | 0.006 | 0.283 | 0.028 | 0.026 | 0.006 | 0.299 | #13 | 0.045 | Not Required | Pass |
| 4 | 0.005 | 0.287 | 0.073 | 0.029 | 0.017 | 0.358 | #13 | 0.120 | Not Required | Pass |
| 5 | 0.005 | 0.175 | 0.034 | 0.028 | 0.009 | 0.179 | #13 | 0.074 | Not Required | Pass |
| 6 | 0.013 | 0.564 | 0.122 | 0.059 | 0.036 | 0.634 | #13 | 0.045 | Not Required | Pass |
| 7 | 0.014 | 0.350 | 0.209 | 0.056 | 0.050 | 0.368 | #13 | 0.074 | Not Required | Pass |
| 8 | 0.006 | 0.118 | 0.194 | 0.032 | 0.021 | 0.210 | #23 | 0.095 | Not Required | Pass |
| 9 | 0.006 | 0.062 | 0.086 | 0.005 | 0.005 | 0.128 | #13 | 0.204 | Not Required | Pass |
| 10 | 0.015 | 0.513 | 0.202 | 0.051 | 0.044 | 0.562 | #21 | 0.080 | Not Required | Pass |
| 11 | 0.008 | 0.103 | 0.200 | 0.037 | 0.021 | 0.222 | #23 | 0.095 | Not Required | Pass |
| 12 | 0.002 | 0.387 | 0.206 | 0.088 | 0.041 | 0.581 | #13 | 0.053 | Not Required | Pass |
| 13 | 0.011 | 0.076 | 0.496 | 0.047 | 0.027 | 0.505 | #23 | 0.286 | Not Required | Pass |
| 14 | 0.006 | 0.055 | 0.488 | 0.042 | 0.027 | 0.496 | #23 | 0.190 | Not Required | Pass |
| 15 | 0.000 | 0.004 | 0.012 | 0.006 | 0.003 | 0.015 | #21 | Not Required | Not Required | Pass |
| 16 | 0.000 | 0.004 | 0.012 | 0.006 | 0.003 | 0.015 | #21 | Not Required | Not Required | Pass |
| 101 | 0.095 | 0.861 | 0.010 | 0.041 | 0.001 | 0.906 | #13 | 0.634 | Not Required | Pass |
| 102 | 0.004 | 0.364 | 0.205 | 0.089 | 0.036 | 0.523 | #13 | 0.035 | Not Required | Pass |
| 103 | 0.013 | 0.540 | 0.080 | 0.053 | 0.012 | 0.611 | #21 | 0.045 | Not Required | Pass |
| 104 | 0.013 | 0.576 | 0.224 | 0.057 | 0.047 | 0.701 | #21 | 0.080 | Not Required | Pass |
| 105 | 0.013 | 0.334 | 0.230 | 0.053 | 0.058 | 0.384 | #21 | 0.074 | Not Required | Pass |
| 106 | 0.013 | 0.595 | 0.079 | 0.060 | 0.013 | 0.630 | #13 | 0.045 | Not Required | Pass |
| 107 | 0.013 | 0.370 | 0.208 | 0.059 | 0.053 | 0.403 | #13 | 0.074 | Not Required | Pass |
| 108 | 0.008 | 0.051 | 0.178 | 0.036 | 0.020 | 0.207 | #21 | 0.095 | Not Required | Pass |
| 109 | 0.018 | 0.049 | 0.049 | 0.002 | 0.000 | 0.098 | #13 | 0.204 | Not Required | Pass |
| 110 | 0.013 | 0.595 | 0.108 | 0.050 | 0.043 | 0.695 | #21 | 0.080 | Not Required | Pass |

| | | | | | | | | | | |
|-----|-------|-------|-------|-------|-------|-------|-----|--------------|--------------|------|
| 110 | 0.015 | 0.395 | 0.196 | 0.059 | 0.045 | 0.665 | #21 | 0.665 | Not Required | Pass |
| 111 | 0.008 | 0.083 | 0.185 | 0.036 | 0.020 | 0.212 | #23 | 0.095 | Not Required | Pass |
| 112 | 0.004 | 0.381 | 0.227 | 0.090 | 0.042 | 0.582 | #13 | 0.035 | Not Required | Pass |
| 113 | 0.012 | 0.129 | 0.532 | 0.047 | 0.027 | 0.630 | #21 | 0.286 | Not Required | Pass |
| 114 | 0.012 | 0.172 | 0.527 | 0.051 | 0.027 | 0.667 | #21 | 0.286 | Not Required | Pass |
| 115 | 0.014 | 0.322 | 0.267 | 0.036 | 0.021 | 0.560 | #21 | 0.473 | Not Required | Pass |
| 116 | 0.006 | 0.298 | 0.265 | 0.040 | 0.021 | 0.537 | #21 | 0.473 | Not Required | Pass |
| 201 | 0.095 | 0.861 | 0.010 | 0.041 | 0.001 | 0.906 | #13 | 0.634 | Not Required | Pass |
| 202 | 0.004 | 0.381 | 0.227 | 0.090 | 0.042 | 0.582 | #13 | 0.035 | Not Required | Pass |
| 203 | 0.013 | 0.595 | 0.079 | 0.060 | 0.013 | 0.630 | #13 | 0.045 | Not Required | Pass |
| 204 | 0.013 | 0.595 | 0.198 | 0.059 | 0.043 | 0.685 | #21 | 0.080 | Not Required | Pass |
| 205 | 0.013 | 0.370 | 0.208 | 0.059 | 0.053 | 0.403 | #13 | 0.074 | Not Required | Pass |
| 206 | 0.013 | 0.540 | 0.080 | 0.053 | 0.012 | 0.611 | #21 | 0.045 | Not Required | Pass |
| 207 | 0.013 | 0.334 | 0.230 | 0.053 | 0.058 | 0.384 | #21 | 0.074 | Not Required | Pass |
| 208 | 0.006 | 0.078 | 0.224 | 0.040 | 0.021 | 0.237 | #21 | 0.095 | Not Required | Pass |
| 209 | 0.018 | 0.049 | 0.049 | 0.002 | 0.000 | 0.098 | #13 | 0.204 | Not Required | Pass |
| 210 | 0.013 | 0.576 | 0.224 | 0.057 | 0.047 | 0.701 | #21 | 0.080 | Not Required | Pass |
| 211 | 0.008 | 0.108 | 0.229 | 0.036 | 0.021 | 0.246 | #21 | 0.095 | Not Required | Pass |
| 212 | 0.004 | 0.364 | 0.205 | 0.089 | 0.036 | 0.523 | #13 | 0.035 | Not Required | Pass |
| 213 | 0.012 | 0.129 | 0.532 | 0.047 | 0.027 | 0.630 | #21 | 0.286 | Not Required | Pass |
| 214 | 0.012 | 0.172 | 0.527 | 0.051 | 0.027 | 0.667 | #21 | 0.286 | Not Required | Pass |
| 215 | 0.015 | 0.273 | 0.268 | 0.036 | 0.020 | 0.495 | #21 | 0.473 | Not Required | Pass |
| 216 | 0.010 | 0.206 | 0.265 | 0.036 | 0.020 | 0.446 | #21 | 0.473 | Not Required | Pass |
| 301 | 0.069 | 0.640 | 0.072 | 0.031 | 0.005 | 0.703 | #13 | 0.634 | Not Required | Pass |
| 302 | 0.002 | 0.387 | 0.206 | 0.088 | 0.041 | 0.581 | #13 | 0.053 | Not Required | Pass |
| 303 | 0.013 | 0.564 | 0.122 | 0.059 | 0.036 | 0.634 | #13 | 0.045 | Not Required | Pass |
| 304 | 0.015 | 0.513 | 0.202 | 0.051 | 0.044 | 0.562 | #21 | 0.080 | Not Required | Pass |
| 305 | 0.014 | 0.350 | 0.209 | 0.056 | 0.050 | 0.368 | #13 | 0.074 | Not Required | Pass |
| 306 | 0.006 | 0.283 | 0.028 | 0.026 | 0.006 | 0.299 | #13 | 0.045 | Not Required | Pass |
| 307 | 0.005 | 0.175 | 0.034 | 0.028 | 0.009 | 0.179 | #13 | 0.074 | Not Required | Pass |
| 308 | 0.000 | 0.004 | 0.012 | 0.006 | 0.003 | 0.015 | #21 | Not Required | Not Required | Pass |
| 309 | 0.006 | 0.062 | 0.086 | 0.005 | 0.005 | 0.128 | #13 | 0.204 | Not Required | Pass |
| 310 | 0.005 | 0.287 | 0.073 | 0.029 | 0.017 | 0.358 | #13 | 0.120 | Not Required | Pass |
| 311 | 0.000 | 0.004 | 0.012 | 0.006 | 0.003 | 0.015 | #21 | Not Required | Not Required | Pass |
| 312 | 0.002 | 0.141 | 0.101 | 0.040 | 0.022 | 0.205 | #21 | 0.053 | Not Required | Pass |
| 313 | 0.011 | 0.076 | 0.496 | 0.047 | 0.027 | 0.504 | #23 | 0.190 | Not Required | Pass |
| 314 | 0.006 | 0.055 | 0.488 | 0.042 | 0.027 | 0.497 | #23 | 0.286 | Not Required | Pass |
| 315 | 0.014 | 0.320 | 0.268 | 0.037 | 0.021 | 0.561 | #21 | 0.473 | Not Required | Pass |
| 316 | 0.006 | 0.315 | 0.261 | 0.032 | 0.021 | 0.549 | #21 | 0.473 | 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 |
|------------|--------------|---------|
|------------|--------------|---------|

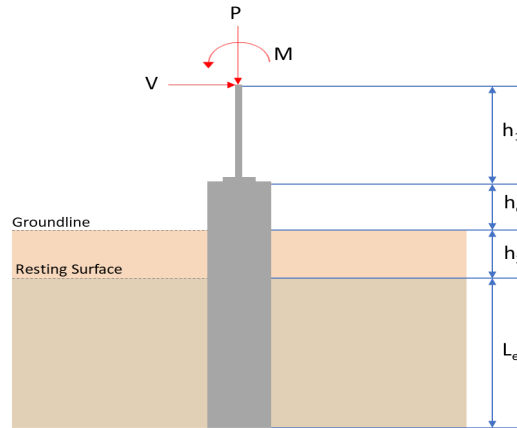
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

| Load Component | ASD | LRFD |
|----------------|--------|--------|
| P (kip) | 5.431 | 8.112 |
| V_x (kip) | -2.115 | -3.544 |
| V_z (kip) | 0.373 | 0.586 |
| M_x (kipft) | 1.722 | 2.695 |
| M_z (kipft) | 31.525 | 53.343 |

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.115 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.33678 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.525 \text{ kipft}) + ((-2.115 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.0199 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.4701 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.373 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.059395 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.722 \text{ kipft}) + ((0.373 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.2742 \text{ kipft/ft}$$

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:

$L_{e,z} = 3.2209 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.4701 \text{ ft}), (3.2209 \text{ ft})]$$

$$L_{e,req} = 6.47 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$Ratio = \frac{(6.47 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.92429$$

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

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

$$q = \frac{(5.431 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.33944 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.33944 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.16972$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.33678 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.0199 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.0199 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.0199 \text{ kipft/ft})) + (4 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8058 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.0199 \text{ kipft/ft})) + (3 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.0199 \text{ kipft/ft})) + (2 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25033 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.0199 \text{ kipft/ft})) + ((-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.94069 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8058 \text{ ft})}{2}$$

$$p_a = 0.36043 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.25033 \text{ kip/ft}^2)}{(0.36043 \text{ kip/ft}^2)}$$

$$Ratio = 0.69453$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.94069 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.8959$$

Status: **PASS**
Ratio: **0.690**

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = 0.059395 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.2742 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2742 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.059395 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.2742 \text{ kipft/ft})) + (4 \times (0.059395 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.96 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.2742 \text{ kipft/ft})) + (3 \times (0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.2742 \text{ kipft/ft})) + (2 \times (0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.050845 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.2742 \text{ kipft/ft})) + ((0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.11806 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.96 \text{ ft})}{2}$$

$$p_a = 0.37199 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.050845 \text{ kip/ft}^2)}{(0.37199 \text{ kip/ft}^2)}$$

$$Ratio = 0.13668$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

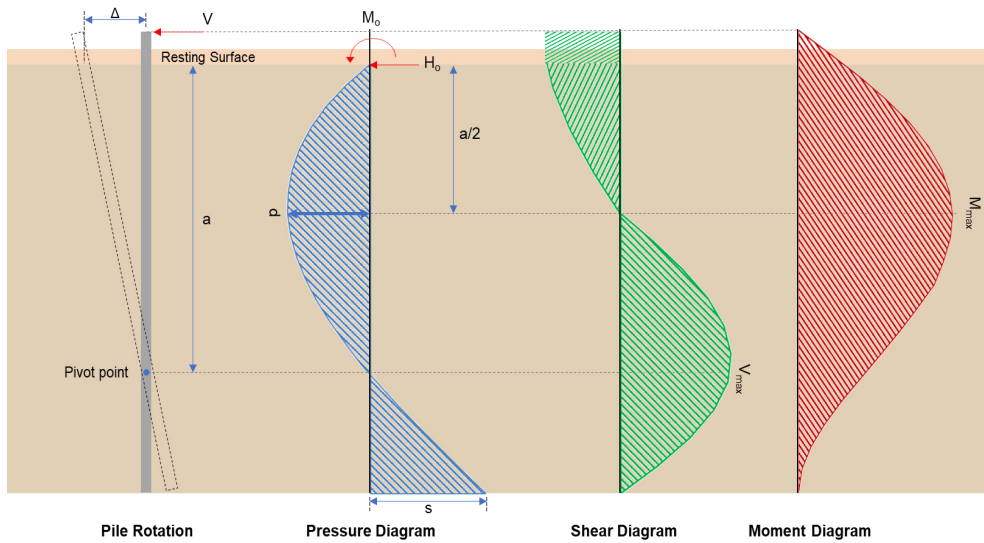
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.11806 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.11244$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.544 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.56433 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.343 \text{ kipft}) + ((-3.544 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.4941 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.4941 \text{ kipft/ft})}{(-0.56433 \text{ kip/ft})}$$

$$E = 15.052 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.4941 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (8.4941 \text{ kipft/ft})) + (4 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = \frac{(-0.56433 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (8.4941 \text{ kip/ft})) + (4 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8047 \text{ ft}$$

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

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

$$V_{max} = ((-0.56433 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8047 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8047 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.08 \text{ kip}$$

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

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

$$M_{max} = ((-0.56433 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(15.052 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 33.842 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.586 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.093312 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.695 \text{ kipft}) + ((0.586 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.42914 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.42914 \text{ kipft/ft})}{(0.093312 \text{ kip/ft})}$$

$$E = 4.599 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.42914 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.093312 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.42914 \text{ kipft/ft})) + (4 \times (0.093312 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9605 \text{ ft}$$

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

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

$$V_{max} = ((0.093312 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.9605 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.9605 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.68162 \text{ kip}$$

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

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

$$M_{max} = ((0.093312 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(4.599 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 2.1517 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.112 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.327 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.327 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | | |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p> | <p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">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> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(8.112 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0030323$</p> | <p>Status: PASS Ratio: 0.000</p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p> | |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.112 \text{ kip} \rightarrow 8112 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8112 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.57 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.57 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.57 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.57 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.8 \text{ kip}$$

Considering x-direction:

V_{max} = 10.08 kip - Maximum shear force in the x-direction,
 Ratio - Capacity

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

$$Ratio = \frac{(10.08 \text{ kip})}{(110.8 \text{ kip})}$$

$$Ratio = 0.090977$$

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

Considering z-direction:

$V_{max} = 0.68162 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.68162 \text{ kip})}{(110.8 \text{ kip})}$$

$$Ratio = 0.0061519$$

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

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:

$M_{max} = 33.842 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(33.842 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.13558$$

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

Considering z-direction:

$M_{max} = 2.1517 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(2.1517 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0086208$$

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

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

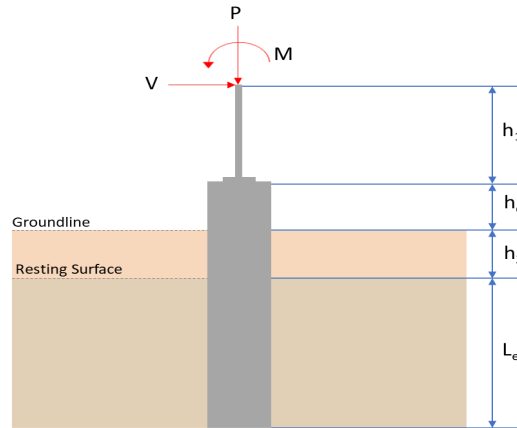
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

| Load Component | ASD | LRFD |
|----------------|--------|--------|
| P (kip) | 5.431 | 8.112 |
| V_x (kip) | -2.115 | -3.544 |
| V_z (kip) | -0.373 | -0.586 |
| M_x (kipft) | -1.722 | -2.695 |
| M_z (kipft) | 31.525 | 53.344 |

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.115 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.33678 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.525 \text{ kipft}) + ((-2.115 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.0199 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.4701 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.373 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.059395 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.722 \text{ kipft}) + ((-0.373 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.2742 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.3787 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.4701 \text{ ft}), (2.3787 \text{ ft})]$$

$$L_{e,req} = 6.47 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.47 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.92429$$

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

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

$$q = \frac{(5.431 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.33944 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.33944 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.16972$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.33678 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.0199 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.0199 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.0199 \text{ kipft/ft})) + (4 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8058 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.0199 \text{ kipft/ft})) + (3 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.0199 \text{ kipft/ft})) + (2 \times (-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25033 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.0199 \text{ kipft/ft})) + ((-0.33678 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.94069 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8058 \text{ ft})}{2}$$

$$p_a = 0.36043 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.25033 \text{ kip/ft}^2)}{(0.36043 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.69453$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.94069 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.8959$$

Status: **PASS**
Ratio: **0.690**

Status: **PASS**
Ratio: **0.900**

Considering z-direction:

$H_o = -0.059395 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.2742 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2742 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.059395 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.2742 \text{ kipft/ft})) + (4 \times (-0.059395 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.96 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.2742 \text{ kipft/ft})) + (3 \times (-0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.2742 \text{ kipft/ft})) + (2 \times (-0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = -0.038867 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.2742 \text{ kipft/ft})) + ((-0.059395 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.016242 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.96 \text{ ft})}{2}$$

$$p_a = 0.37199 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.038867 \text{ kip/ft}^2)}{(0.37199 \text{ kip/ft}^2)}$$

$$Ratio = -0.10448$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$$

$$p_s = 1.05 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

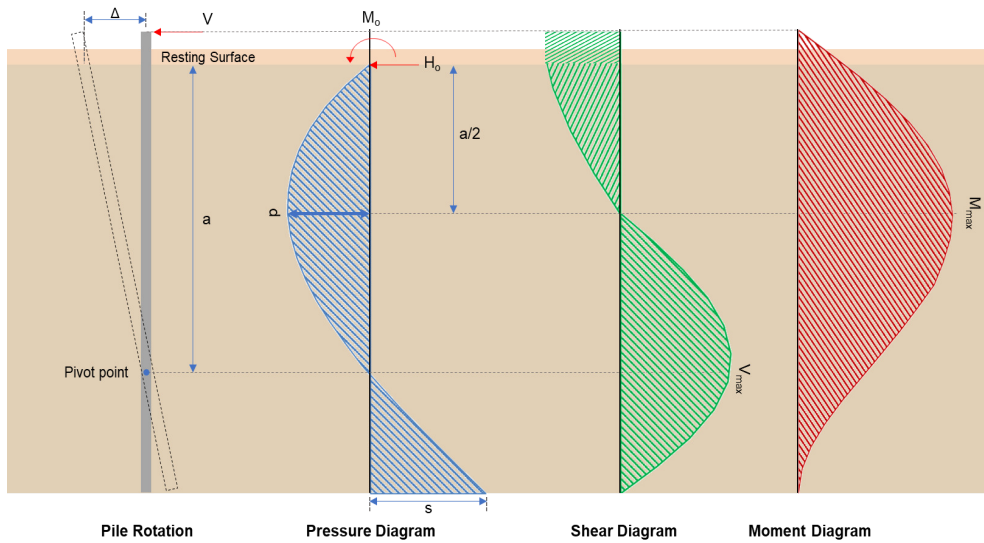
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.016242 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.015469$$

Status: **PASS**
Ratio: **-0.100**

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.544 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.56433 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.344 \text{ kipft}) + ((-3.544 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.4943 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.4943 \text{ kipft/ft})}{(-0.56433 \text{ kip/ft})}$$

$$E = 15.052 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.4943 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (8.4943 \text{ kipft/ft})) + (4 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = \frac{(-0.56433 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (8.4943 \text{ kip/ft})) + (4 \times (-0.56433 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8047 \text{ ft}$$

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

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

$$V_{max} = ((-0.56433 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8047 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8047 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.08 \text{ kip}$$

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

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

$$M_{max} = ((-0.56433 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(15.052 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (15.052 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8047 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 33.843 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.586 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.093312 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.695 \text{ kipft}) + ((-0.586 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.42914 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.42914 \text{ kipft/ft})}{(-0.093312 \text{ kip/ft})}$$

$$E = 4.599 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.42914 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.093312 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.42914 \text{ kipft/ft})) + (4 \times (-0.093312 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9605 \text{ ft}$$

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

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

$$V_{max} = ((-0.093312 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.9605 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.9605 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.68162 \text{ kip}$$

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

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

$$M_{max} = ((-0.093312 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(4.599 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.599 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.9605 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 2.1517 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.112 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.327 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.327 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | | |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p> | <p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">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> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(8.112 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0030323$</p> | <p>Status: PASS Ratio: 0.000</p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p> | |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.112 \text{ kip} \rightarrow 8112 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8112 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.57 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.57 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.57 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.57 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.8 \text{ kip}$$

Considering x-direction:

V_{max} = 10.08 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(10.08 \text{ kip})}{(110.8 \text{ kip})}$$

$$Ratio = 0.090978$$

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

Considering z-direction:

$V_{max} = 0.68162 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.68162 \text{ kip})}{(110.8 \text{ kip})}$$

$$Ratio = 0.0061519$$

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

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:

$M_{max} = 33.843 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(33.843 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.13559$$

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

Considering z-direction:

$M_{max} = 2.1517 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(2.1517 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0086208$$

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

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

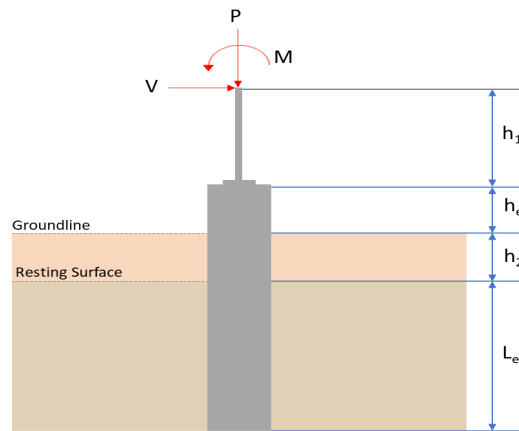
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

| Load Component | ASD | LRFD |
|----------------|--------|--------|
| P (kip) | 7.447 | 11.184 |
| V_x (kip) | -2.795 | -4.659 |
| V_z (kip) | 0.044 | 0.077 |
| M_x (kipft) | 0.197 | 0.344 |
| M_z (kipft) | 41.873 | 71.720 |

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.795 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.44506 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.873 \text{ kipft}) + ((-2.795 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6677 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.02 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.044 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0070064 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.197 \text{ kipft}) + ((0.044 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.031369 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.4619 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.02 \text{ ft}), (1.4619 \text{ ft})]$$

$$L_{e,req} = 7.02 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.02 \text{ ft})}{(7.5 \text{ ft})}$$

$$\text{Ratio} = 0.936$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.447 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.46544 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.46544 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.23272$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.44506 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 6.6677 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.6677 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (6.6677 \text{ kipft/ft})) + (4 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1564 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.6677 \text{ kipft/ft})) + (3 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.6677 \text{ kipft/ft})) + (2 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.27758 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (6.6677 \text{ kipft/ft})) + ((-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0664 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1564 \text{ ft})}{2}$$

$$p_a = 0.38673 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.27758 \text{ kip/ft}^2)}{(0.38673 \text{ kip/ft}^2)}$$

$$Ratio = 0.71776$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.0664 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.9479$$

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

Status: **PASS**
Ratio: **0.950**

Considering z-direction:

$H_o = 0.0070064 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.031369 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.031369 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.031369 \text{ kipft/ft})) + (4 \times (0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3297 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.031369 \text{ kipft/ft})) + (3 \times (0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (0.031369 \text{ kipft/ft})) + (2 \times (0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.0053652 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.031369 \text{ kipft/ft})) + ((0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 0.012297 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3297 \text{ ft})}{2}$$

$$p_a = 0.39973 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0053652 \text{ kip/ft}^2)}{(0.39973 \text{ kip/ft}^2)}$$

$$Ratio = 0.013422$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

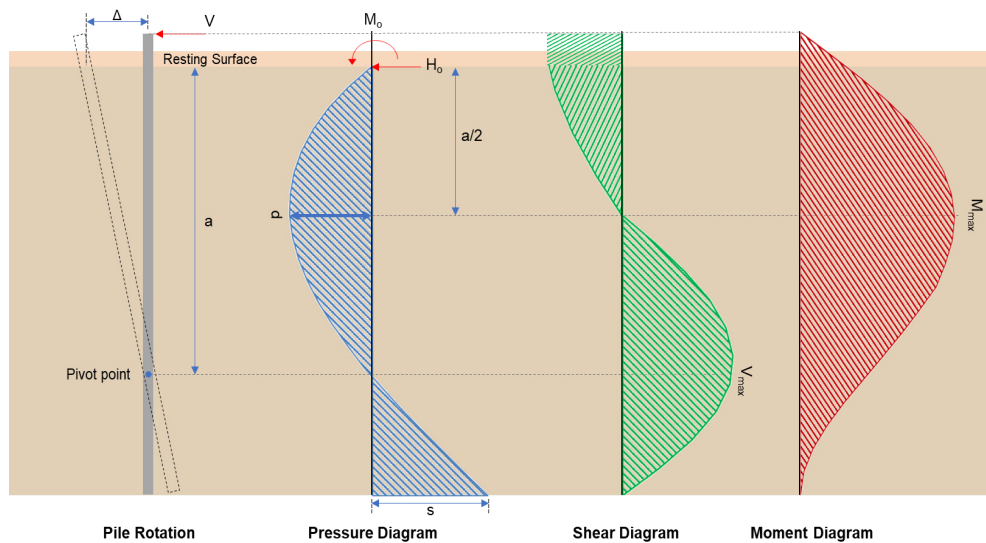
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.012297 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.010931$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.659 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.74188 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(71.72 \text{ kipft}) + ((-4.659 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.42 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.42 \text{ kipft/ft})}{(-0.74188 \text{ kip/ft})}$$

$$E = 15.394 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.42 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (11.42 \text{ kipft/ft})) + (4 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = \frac{(6 \times (11.42 \text{ kipft/ft})) + (4 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft}))}{}$$

$$a = 5.1532 \text{ ft}$$

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

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

$$V_{max} = ((-0.74188 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.1532 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.1532 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.737 \text{ kip}$$

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

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

$$M_{max} = ((-0.74188 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(15.394 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1532 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.1532 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.1532 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 45.74 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.077 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.012261 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.344 \text{ kipft}) + ((0.077 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.054777 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.054777 \text{ kipft/ft})}{(0.012261 \text{ kip/ft})}$$

$$E = 4.4675 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.054777 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (0.012261 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.054777 \text{ kipft/ft})) + (4 \times (0.012261 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3301 \text{ ft}$$

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

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

$$V_{max} = ((0.012261 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.4675 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3301 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (4.4675 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3301 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.084287 \text{ kip}$$

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

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

$$M_{max} = ((0.012261 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(4.4675 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3301 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (4.4675 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3301 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.4675 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3301 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.28319 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(11.184 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.224 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.224 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | | |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p> | <p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(11.184 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0041806$ | <p>Status: PASS Ratio: 0.000</p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</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> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.184 \text{ kip} \rightarrow 11184 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(11184 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.98 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.98 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.98 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.98 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.07 \text{ kip}$$

Considering x-direction:

V_{max} = 12.737 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.737 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.11468$$

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

Considering z-direction:

$V_{max} = 0.084287 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.084287 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.0007589$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

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:

$M_{max} = 45.74 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(45.74 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.18325$$

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

Considering z-direction:

$M_{max} = 0.28319 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.28319 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0011346$$

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

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

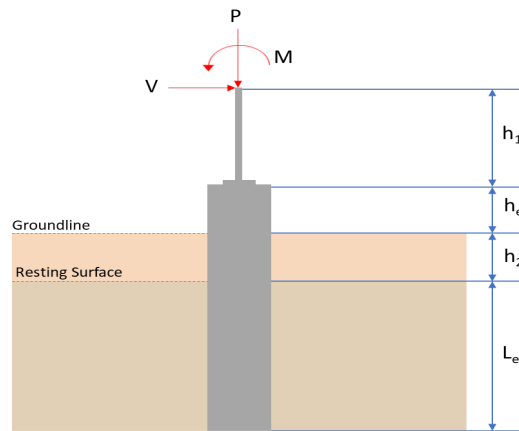
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 7.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

| Load Component | ASD | LRFD |
|----------------|--------|--------|
| P (kip) | 7.447 | 11.184 |
| V_x (kip) | -2.795 | -4.659 |
| V_z (kip) | -0.044 | -0.077 |
| M_x (kipft) | -0.197 | -0.345 |
| M_z (kipft) | 41.873 | 71.721 |

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.795 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.44506 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.873 \text{ kipft}) + ((-2.795 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6677 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.02 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.044 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0070064 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.197 \text{ kipft}) + ((-0.044 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.031369 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.256 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.02 \text{ ft}), (1.256 \text{ ft})]$$

$$L_{e,req} = 7.02 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.02 \text{ ft})}{(7.5 \text{ ft})}$$

$$\text{Ratio} = 0.936$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.447 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.46544 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.46544 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.23272$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.44506 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 6.6677 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.6677 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (6.6677 \text{ kipft/ft})) + (4 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1564 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.6677 \text{ kipft/ft})) + (3 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (6.6677 \text{ kipft/ft})) + (2 \times (-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.27758 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (6.6677 \text{ kipft/ft})) + ((-0.44506 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0664 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.1564 \text{ ft})}{2}$$

$$p_a = 0.38673 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.27758 \text{ kip/ft}^2)}{(0.38673 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71776$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.0664 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.9479$$

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

Status: **PASS**
Ratio: **0.950**

Considering z-direction:

$H_o = -0.0070064 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.031369 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.031369 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.031369 \text{ kipft/ft})) + (4 \times (-0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3297 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.031369 \text{ kipft/ft})) + (3 \times (-0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (0.031369 \text{ kipft/ft})) + (2 \times (-0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = -0.0012555 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.031369 \text{ kipft/ft})) + ((-0.0070064 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 0.001087 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3297 \text{ ft})}{2}$$

$$p_a = 0.39973 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0012555 \text{ kip/ft}^2)}{(0.39973 \text{ kip/ft}^2)}$$

$$Ratio = -0.003141$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

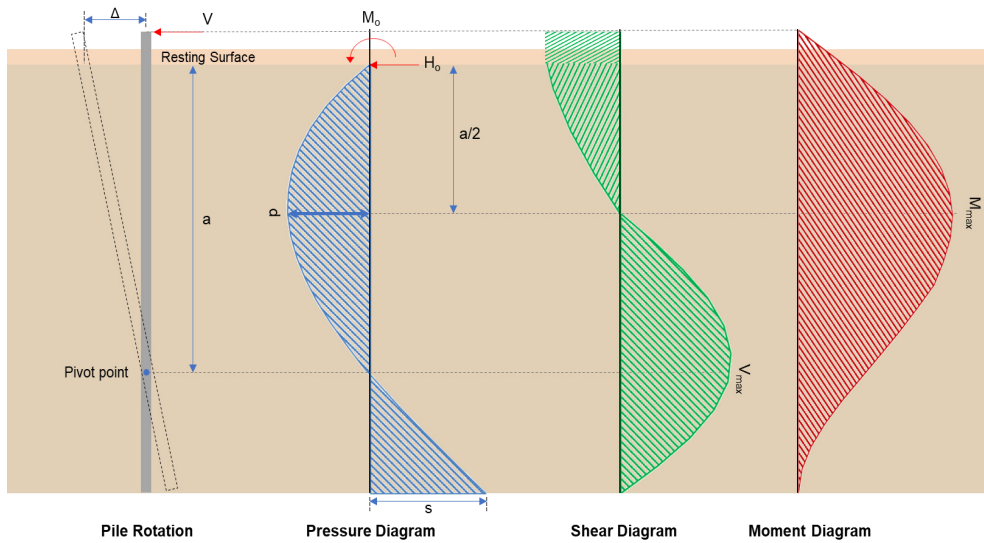
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.001087 \text{ kip/ft}^2)}{(1.125 \text{ kip/ft}^2)}$$

$$Ratio = 0.00096627$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.659 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.74188 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(71.721 \text{ kipft}) + ((-4.659 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.421 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.421 \text{ kipft/ft})}{(-0.74188 \text{ kip/ft})}$$

$$E = 15.394 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.421 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (11.421 \text{ kipft/ft})) + (4 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = \frac{(6 \times (11.421 \text{ kipft/ft})) + (4 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft}))}{(6 \times (11.421 \text{ kipft/ft})) + (4 \times (-0.74188 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1532 \text{ ft}$$

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

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

$$V_{max} = ((-0.74188 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{5.1532 \text{ ft}}{(7.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{5.1532 \text{ ft}}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.738 \text{ kip}$$

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

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

$$M_{max} = ((-0.74188 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{15.394 \text{ ft}}{(7.5 \text{ ft})} + \frac{5.1532 \text{ ft}}{2 \times (7.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{5.1532 \text{ ft}}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (15.394 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{5.1532 \text{ ft}}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 45.741 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.077 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.012261 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.345 \text{ kipft}) + ((-0.077 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.054936 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.054936 \text{ kipft/ft})}{(-0.012261 \text{ kip/ft})}$$

$$E = 4.4805 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.054936 \text{ kipft/ft}) \times (7.5 \text{ ft})) + (3 \times (-0.012261 \text{ kip/ft}) \times (7.5 \text{ ft})^2)}{(6 \times (0.054936 \text{ kipft/ft})) + (4 \times (-0.012261 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3296 \text{ ft}$$

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

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

$$V_{max} = ((-0.012261 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.4805 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3296 \text{ ft})}{(7.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (4.4805 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3296 \text{ ft})}{(7.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.084436 \text{ kip}$$

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

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

$$M_{max} = ((-0.012261 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(4.4805 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.3296 \text{ ft})}{2 \times (7.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (4.4805 \text{ ft})}{(7.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.3296 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.4805 \text{ ft})}{(7.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.3296 \text{ ft})}{2 \times (7.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.28375 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(11.184 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.224 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.224 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

| | | |
|---|---|--|
| <p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p> | <p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">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> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(11.184 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0041806$</p> | <p>Status: PASS Ratio: 0.000</p> |
| <p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p> | <p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p> | |

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.184 \text{ kip} \rightarrow 11184 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(11184 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.98 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.98 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.98 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.98 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.07 \text{ kip}$$

Considering x-direction:

V_{max} = 12.738 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.738 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.11469$$

Considering z-direction:

$V_{max} = 0.084436 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.084436 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.00076024$$

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

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

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:

$M_{max} = 45.741 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(45.741 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.18326$$

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

Considering z-direction:

$M_{max} = 0.28375 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.28375 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0011368$$

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