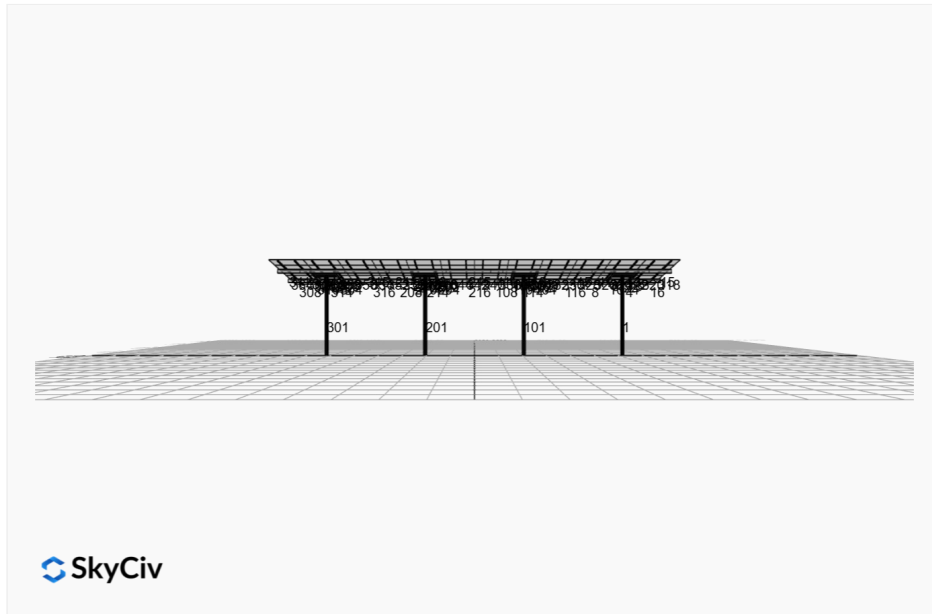


**Project Name:** MTSOLAR\_8LC7LFHKD82H      **Date:** Tue Jan 07 2025  
**Location:** 821 W Hwy 50, O'Fallon, IL 62269, USA      **Number of Modules:** 60  
**Unique ID:** 4P-17-6TOP-HD-45-L-5Hx12W-9ABL      **Number of Poles:** 4  
**Dealer:** \_\_\_\_\_      **Date Sold:** \_\_\_\_\_



<b>Array Dimensions N/S</b>	18.96 ft
<b>Array Dimensions E/W</b>	66.00 ft
<b>Winter Tilt Angle</b>	10
<b>Front Edge Clearance</b>	12 ft

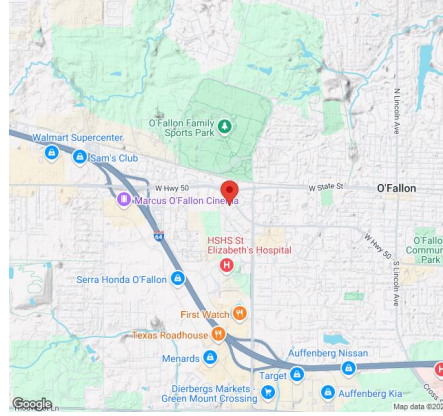
### MT Solar Bill of Materials (4P-17-6TOP-HD-45-L-5Hx12W-9ABL)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	4
MTS-HF-HD	H-Frame Assembly-HD	4
MTS-HD-Wing-45	45IN HD Wing	4
MTS-HD-Splice-57	57IN HD Splice	12
MTS-CLAMP-ANGLE-4PK	Angle Clamp	12

### Rail Bill of Materials

Part	Qty
Rails (225in)	24
Rail Attachment	96
Module Mid Clamp	96
Module End Clamp	48
Ground Lug	12

## Site Details:



**Site Address:** 821 W Hwy 50, O'Fallon, IL 62269, USA

### Array Specification

<b>Duty Classification:</b>	HD
<b>Module Width:</b>	45.00 in
<b>Module Length:</b>	65.00in
<b>Number of Rows:</b>	5
<b>Number of Columns:</b>	12
<b>Total Number of Modules:</b>	60
<b>Winter Tilt Angle:</b>	10
<b>Front Edge Clearance:</b>	12
<b>Total Array Height at Tilt:</b>	15.29 ft
<b>Total Frame Length:</b>	66.00 ft
<b>Frame Weight:</b>	4495 lbs
<b>Array Dimensions N/S:</b>	18.96 ft
<b>Array Dimensions E/W:</b>	66.00 ft
<b>Rail Length:</b>	227.50 in
<b>Rail Spacing:</b>	2.75 ft

### Support Specifications

<b>Pole Size:</b>	6in Pipe Sch 40
<b>Pole Length above Grade:</b>	13.65 ft
<b>Number of Poles:</b>	4
<b>Pole Spacing:</b>	17 ft

### Foundation Specifications

<b>Foundation Type:</b>	Round
<b>Foundation Dimensions:</b>	Ø36 in
<b>Foundation Depth (below grade):</b>	Pile 1: 7.75 ft Pile 2: 7.75 ft Pile 3: 7.75 ft Pile 4: 7.75 ft
<b>Foundation Volume:</b>	8.116 y <sup>3</sup>

### Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	C
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	821 W Hwy 50, O'Fallon, IL 62269, USA
<b>Wind Speed:</b>	101 mph

**Snow Load:**

20 psf

### **Design Disclaimer**

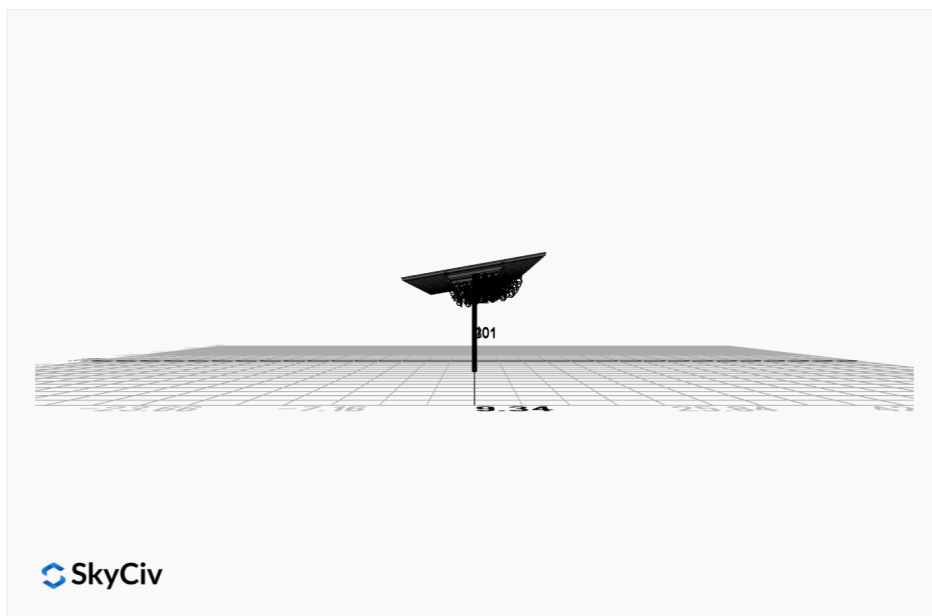
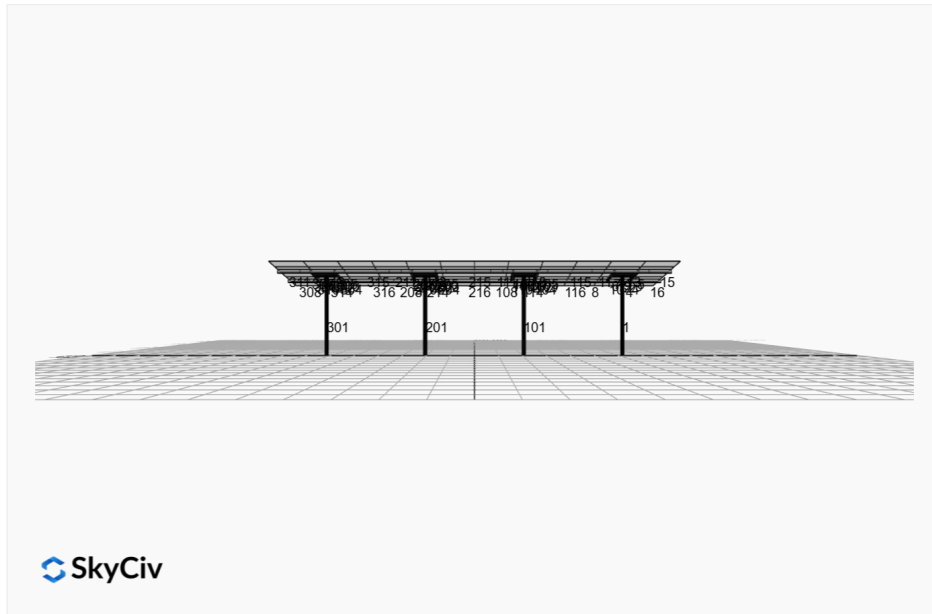
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

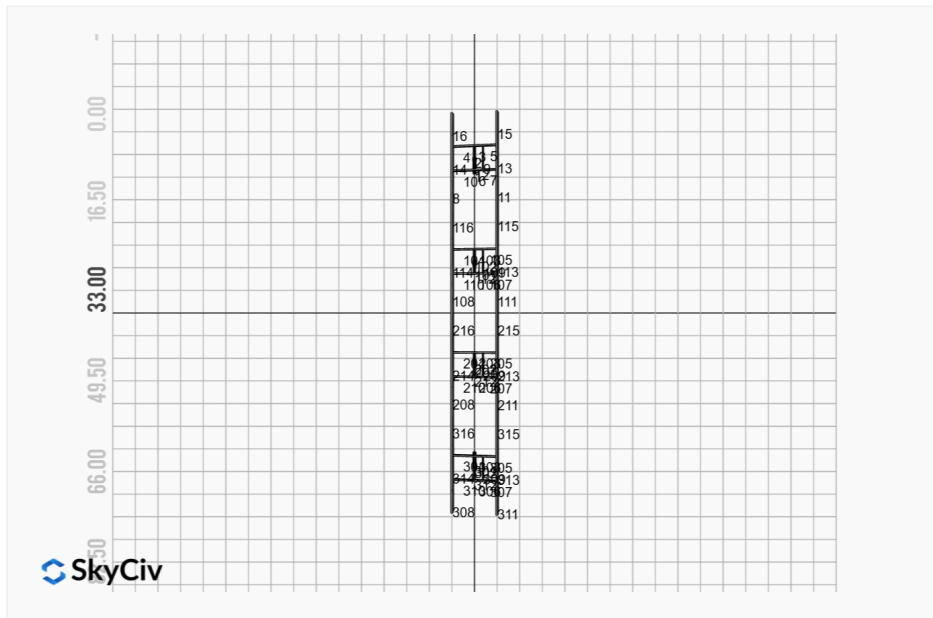
## AutoDesigner Input

```
{ "wind_speed_override": null, "snow_load_override": null, "direct_snow_load": false, "add_angle_brace": false, "product_type": "Beam", "designer_name": "jm", "designer_email": "jasonmitchell@gridsolarllc.com", "designer_phone": "", "project_id": "MTSOLAR_8LC7LFHKD82H", "site_address": "821 W Hwy 50, O'Fallon, IL 62269, USA", "module_width": 45, "module_length": 65, "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": 10, "ground_clearance": 12, "risk_category": "I", "exposure_category": "C", "frame_duty_override": "auto", "pole_override": "auto", "soil_type": "sand", "customer_foundation_override": "36_Round", "foundation_type": "Round", "foundation_size": 36, "check_rails": false }
```

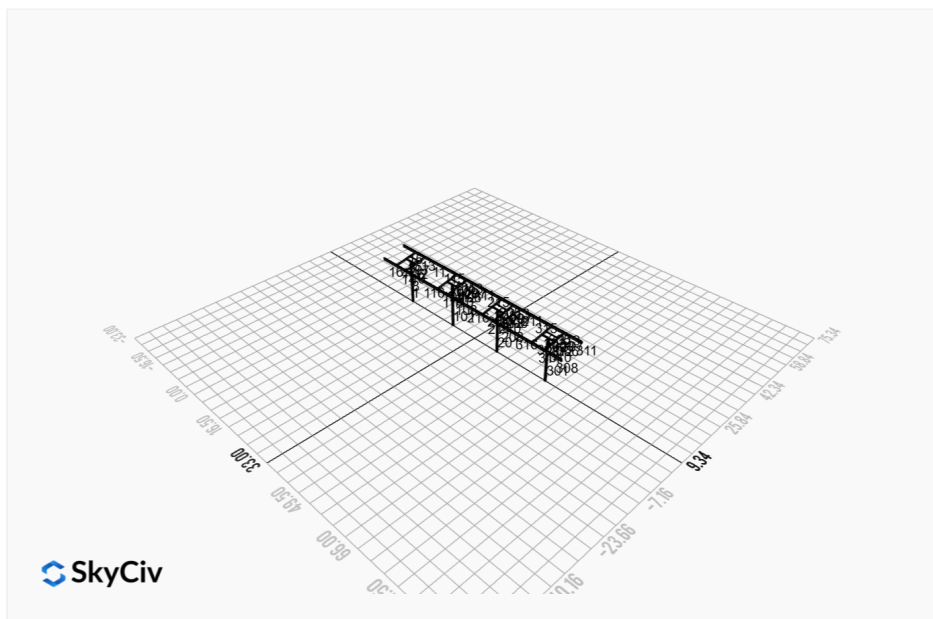
## Design Notes:

- 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)
- Foundation Design and Sizing is approximate only





SkyCiv

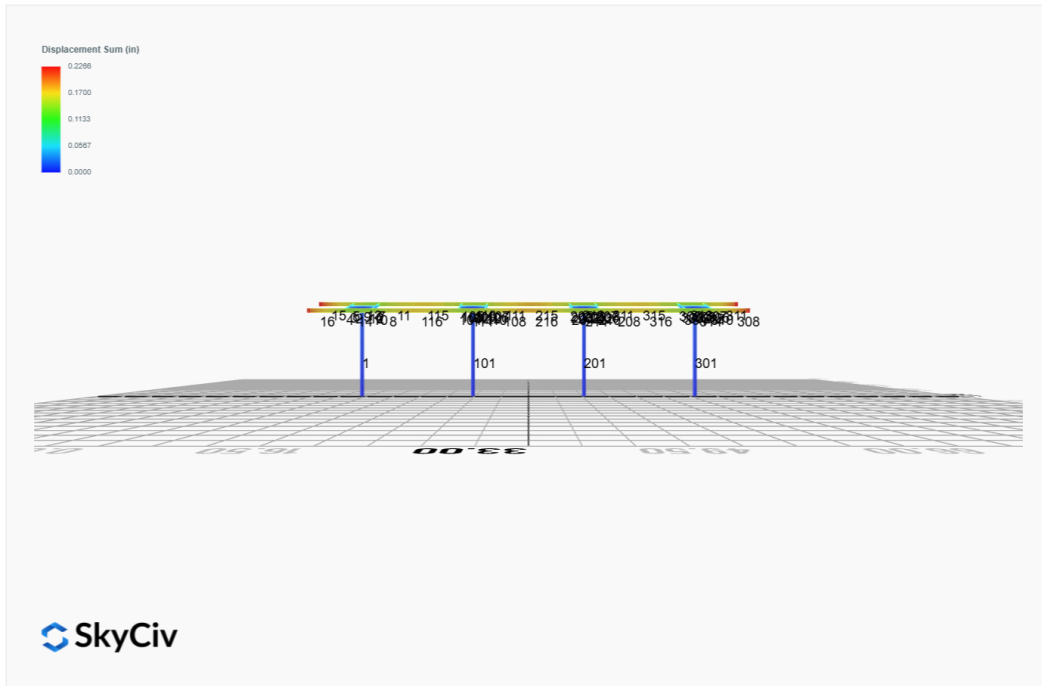


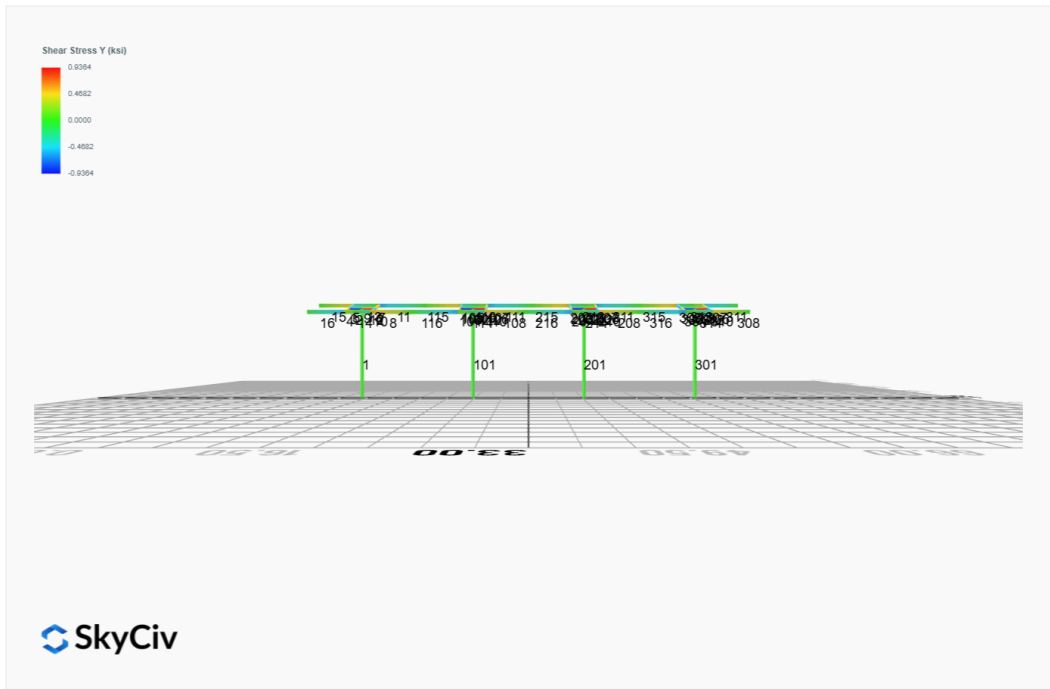
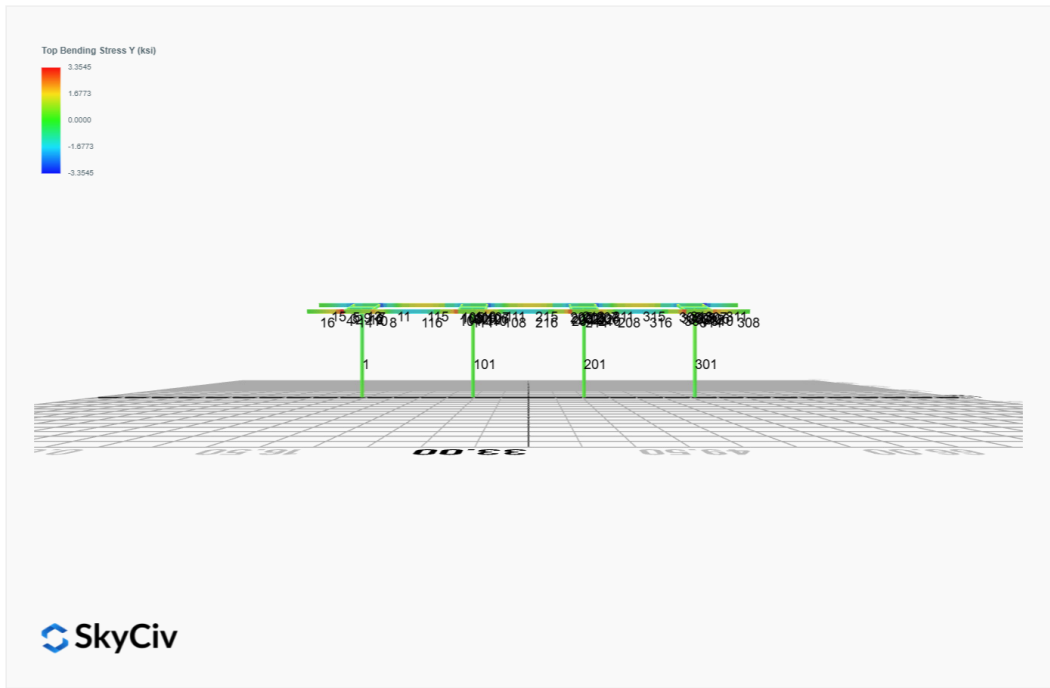
SkyCiv

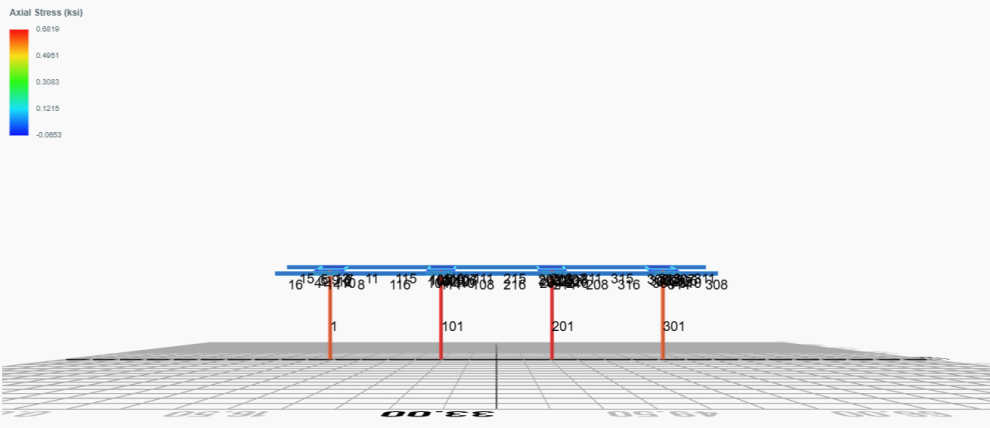


SkyCiv

# FEM Results (Envelope Worst Case for each member)







## Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0016	2.1970	-0.0062	-0.0272	0.0055	0.0468
ULS: 2. D + L	-0.0016	2.1970	-0.0062	-0.0272	0.0055	0.0468
ULS: 3. D + (S or Lr or R)	-0.0048	5.8434	-0.0191	-0.0837	0.0170	0.0899
ULS: 3. D + (S or Lr or R)	-0.0016	2.1970	-0.0062	-0.0272	0.0055	0.0468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0040	4.9318	-0.0159	-0.0695	0.0141	0.0791
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0016	2.1970	-0.0062	-0.0272	0.0055	0.0468
ULS: 5b. D + 0.7E	-0.0016	2.1970	-0.0062	-0.0272	0.0055	0.0468
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0040	4.9318	-0.0159	-0.0695	0.0141	0.0791
ULS: 8. 0.6D + 0.7E	-0.0009	1.3182	-0.0037	-0.0163	0.0033	0.0281
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6544	5.8421	-0.0171	-0.0756	0.0081	12.6341
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6544	5.8421	-0.0171	-0.0756	0.0081	12.6341
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4514	-0.3586	0.0024	0.0106	0.0016	-3.8407
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4018	-0.0284	-0.0004	-0.0017	0.0059	-13.2736
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4936	7.6657	-0.0240	-0.1059	0.0160	9.5196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4936	7.6657	-0.0240	-0.1059	0.0160	9.5196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3357	3.0151	-0.0094	-0.0413	0.0112	-2.8365
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2985	3.2628	-0.0115	-0.0504	0.0144	-9.9112
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4912	4.9308	-0.0144	-0.0635	0.0074	9.4873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4912	4.9308	-0.0144	-0.0635	0.0074	9.4873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3382	0.2803	0.0002	0.0011	0.0026	-2.8688
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3010	0.5279	-0.0019	-0.0080	0.0058	-9.9435
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6538	4.9633	-0.0146	-0.0648	0.0059	12.6154
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6538	4.9633	-0.0146	-0.0648	0.0059	12.6154
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4520	-1.2374	0.0049	0.0214	-0.0006	-3.8594
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4024	-0.9072	0.0020	0.0092	0.0037	-13.2924

### 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	11.5084
Shear X	-1.0930
Shear Z	-0.0371
Moment X	-0.1647
Moment Y (Twist)	0.0269
Moment Z	23.5871

### 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	7.6657
Shear X	-0.6544
Shear Z	-0.0240
Moment X	-0.1059
Moment Y (Twist)	0.0170
Moment Z	13.2924

## 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	0.0016	2.2722	0.0025	0.0112	-0.0010	0.0120
ULS: 2. D + L	0.0016	2.2722	0.0025	0.0112	-0.0010	0.0120
ULS: 3. D + (S or Lr or R)	0.0048	6.0783	0.0078	0.0348	-0.0032	-0.0182
ULS: 3. D + (S or Lr or R)	0.0016	2.2722	0.0025	0.0112	-0.0010	0.0120
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0040	5.1268	0.0065	0.0289	-0.0027	-0.0106

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0016	2.2722	0.0025	0.0112	-0.0010	0.0120
ULS: 5b. D + 0.7E	0.0016	2.2722	0.0025	0.0112	-0.0010	0.0120
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0040	5.1268	0.0065	0.0289	-0.0027	-0.0106
ULS: 8. 0.6D + 0.7E	0.0009	1.3633	0.0015	0.0067	-0.0006	0.0072
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6583	6.0714	0.0095	0.0420	-0.0078	12.7994
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6583	6.0714	0.0095	0.0420	-0.0078	12.7994
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4691	-0.3929	-0.0017	-0.0074	0.0019	-3.9764
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3994	-0.0463	-0.0022	-0.0094	0.0048	-13.4483
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4909	7.9762	0.0118	0.0520	-0.0077	9.5799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4909	7.9762	0.0118	0.0520	-0.0077	9.5799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3547	3.1280	0.0033	0.0149	-0.0004	-3.0019
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3024	3.3879	0.0029	0.0134	0.0017	-10.1058
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4933	5.1216	0.0078	0.0343	-0.0061	9.6025
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4933	5.1216	0.0078	0.0343	-0.0061	9.6025
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3522	0.2734	-0.0007	-0.0028	0.0012	-2.9793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3000	0.5333	-0.0010	-0.0043	0.0033	-10.0832
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6589	5.1625	0.0085	0.0375	-0.0074	12.7946
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6589	5.1625	0.0085	0.0375	-0.0074	12.7946
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4685	-1.3018	-0.0027	-0.0119	0.0023	-3.9812
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3988	-0.9552	-0.0032	-0.0139	0.0052	-13.4531

### 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	11.9823
Shear X	-1.0997
Shear Z	0.0175
Moment X	0.0780
Moment Y (Twist)	0.0141
Moment Z	23.9210

### 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	7.9762
Shear X	-0.6589
Shear Z	0.0118
Moment X	0.0520
Moment Y (Twist)	0.0078
Moment Z	13.4531

### 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	0.0016	2.2722	-0.0025	-0.0112	0.0010	0.0120
ULS: 2. D + L	0.0016	2.2722	-0.0025	-0.0112	0.0010	0.0120
ULS: 3. D + (S or Lr or R)	0.0048	6.0783	-0.0078	-0.0348	0.0032	-0.0182
ULS: 3. D + (S or Lr or R)	0.0016	2.2722	-0.0025	-0.0112	0.0010	0.0120
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0040	5.1268	-0.0065	-0.0289	0.0027	-0.0106
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0016	2.2722	-0.0025	-0.0112	0.0010	0.0120
ULS: 5b. D + 0.7E	0.0016	2.2722	-0.0025	-0.0112	0.0010	0.0120
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0040	5.1268	-0.0065	-0.0289	0.0027	-0.0106
ULS: 8. 0.6D + 0.7E	0.0009	1.3633	-0.0015	-0.0067	0.0006	0.0072
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6583	6.0714	-0.0095	-0.0420	0.0078	12.7994
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6583	6.0714	-0.0095	-0.0420	0.0078	12.7994
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4691	-0.3929	0.0017	0.0074	-0.0019	-3.9764
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.3994	-0.0463	0.0022	0.0094	-0.0048	-13.4483

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4909	7.9762	-0.0118	-0.0520	0.0077	9.5799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4909	7.9762	-0.0118	-0.0520	0.0077	9.5799
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3547	3.1280	-0.0033	-0.0149	0.0004	-3.0019
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3024	3.3879	-0.0029	-0.0134	-0.0017	-10.1058
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4933	5.1216	-0.0078	-0.0343	0.0061	9.6025
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4933	5.1216	-0.0078	-0.0343	0.0061	9.6025
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3522	0.2734	0.0007	0.0028	-0.0012	-2.9793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3000	0.5333	0.0010	0.0043	-0.0033	-10.0832
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6589	5.1625	-0.0085	-0.0375	0.0074	12.7946
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6589	5.1625	-0.0085	-0.0375	0.0074	12.7946
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4685	-1.3018	0.0027	0.0119	-0.0023	-3.9812
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.3988	-0.9552	0.0032	0.0139	-0.0052	-13.4531

### 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	11.9823
Shear X	-1.0997
Shear Z	-0.0175
Moment X	-0.0779
Moment Y (Twist)	0.0141
Moment Z	23.9209

### 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	7.9762
Shear X	-0.6589
Shear Z	-0.0118
Moment X	-0.0520
Moment Y (Twist)	0.0078
Moment Z	13.4531

### 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	-0.0016	2.1970	0.0062	0.0272	-0.0055	0.0468
ULS: 2. D + L	-0.0016	2.1970	0.0062	0.0272	-0.0055	0.0468
ULS: 3. D + (S or Lr or R)	-0.0048	5.8434	0.0191	0.0837	-0.0170	0.0899
ULS: 3. D + (S or Lr or R)	-0.0016	2.1970	0.0062	0.0272	-0.0055	0.0468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0040	4.9318	0.0159	0.0695	-0.0141	0.0791
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0016	2.1970	0.0062	0.0272	-0.0055	0.0468
ULS: 5b. D + 0.7E	-0.0016	2.1970	0.0062	0.0272	-0.0055	0.0468
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0040	4.9318	0.0159	0.0695	-0.0141	0.0791
ULS: 8. 0.6D + 0.7E	-0.0009	1.3182	0.0037	0.0163	-0.0033	0.0281
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.6544	5.8421	0.0171	0.0756	-0.0081	12.6341
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.6544	5.8421	0.0171	0.0756	-0.0081	12.6341
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.4514	-0.3586	-0.0024	-0.0106	-0.0016	-3.8407
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.4018	-0.0284	0.0004	0.0017	-0.0059	-13.2736
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4936	7.6657	0.0240	0.1059	-0.0160	9.5196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4936	7.6657	0.0240	0.1059	-0.0160	9.5196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3357	3.0151	0.0094	0.0413	-0.0112	-2.8365
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2985	3.2628	0.0115	0.0504	-0.0144	-9.9112
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.4912	4.9308	0.0144	0.0635	-0.0074	9.4873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.4912	4.9308	0.0144	0.0635	-0.0074	9.4873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.3382	0.2803	-0.0002	-0.0011	-0.0026	-2.8688
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.3010	0.5279	0.0019	0.0080	-0.0058	-9.9435

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.6538	4.9633	0.0146	0.0648	-0.0059	12.6154
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.6538	4.9633	0.0146	0.0648	-0.0059	12.6154
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.4520	-1.2374	-0.0049	-0.0214	0.0006	-3.8594
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.4024	-0.9072	-0.0020	-0.0092	-0.0037	-13.2924

### 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	11.5084
Shear X	-1.0930
Shear Z	0.0371
Moment X	0.1647
Moment Y (Twist)	0.0268
Moment Z	23.5869

### 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	7.6657
Shear X	-0.6544
Shear Z	0.0240
Moment X	0.1059
Moment Y (Twist)	0.0170
Moment Z	13.2924

# Project Details

Design Code: AISC 360-16 LRFD  
 Provision: LRFD  
 Country: United States  
  
 User Name: sales@mtsolar.us  
 Project Name: MTSOLAR\_8LC7LFHKD82H  
 Unit System: imperial



## Design Input Information

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

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

**Section Dimensions**

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

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

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

Section Properties								
ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	$I_{y0}$ (in <sup>4</sup> )	$I_{z0}$ (in <sup>4</sup> )	$I_w$ (in <sup>6</sup> )	$S_{y0}$ (in <sup>3</sup> )	$S_{z0}$ (in <sup>3</sup> )





314	19	4.88	4.00	0	9,1.13,1.11,1.11,1.12,1.38	0	0	1
315	19	4.84	4.84	7.4 5	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.18,1.17,1.17,1.16,1.17	30 0	20 0	1
316	19	4.84	4.84	7.4 5	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.18,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.16,1.16,1.19	30 0	20 0	1

## Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	53.76	42.30	42.30	75.35	75.35
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	105.13	15.79	11.10	42.08	23.28
5	116.10	111.72	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	25.44	6.12	40.24	43.62
14	133.20	85.85	25.51	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	251.16	53.76	42.30	42.30	75.35	75.35
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	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	24.16	6.12	40.24	43.62
114	133.20	85.85	24.24	6.12	40.24	43.62
115	133.20	86.20	25.68	6.12	40.24	43.62
116	133.20	86.20	25.67	6.12	40.24	43.62
201	251.16	53.76	42.30	42.30	75.35	75.35
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	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	24.16	6.12	40.24	43.62
214	133.20	85.85	24.24	6.12	40.24	43.62
215	133.20	86.20	25.88	6.12	40.24	43.62
216	133.20	86.20	25.98	6.12	40.24	43.62
301	251.16	53.76	42.30	42.30	75.35	75.35
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	111.72	15.79	11.10	42.08	23.28
308	133.20	52.83	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	105.13	15.79	11.10	42.08	23.28
311	133.20	52.83	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	25.44	6.12	40.24	43.62
314	133.20	85.85	25.51	6.12	40.24	43.62
315	133.20	86.20	26.56	6.12	40.24	43.62
316	133.20	86.20	26.68	6.12	40.24	43.62

## Design Ratio

Member ID	P	M <sub>z</sub>	M <sub>y</sub>	V <sub>y</sub>	V <sub>z</sub>	(P,M <sub>z</sub> ,M <sub>y</sub> )	Worst LC	KL/r	δ	Status
1	0.214	0.558	0.008	0.015	0.000	0.632	#13	0.766	Not Required	Pass
2	0.001	0.456	0.053	0.095	0.009	0.497	#21	0.053	Not Required	Pass
3	0.003	0.696	0.021	0.070	0.004	0.718	#21	0.045	Not Required	Pass
4	0.003	0.622	0.040	0.063	0.009	0.650	#21	0.123	Not Required	Pass
5	0.003	0.431	0.043	0.069	0.011	0.441	#21	0.115	Not Required	Pass
6	0.003	0.683	0.021	0.069	0.004	0.704	#21	0.045	Not Required	Pass
7	0.003	0.424	0.044	0.068	0.011	0.434	#21	0.074	Not Required	Pass
8	0.000	0.056	0.031	0.039	0.005	0.085	#21	0.095	Not Required	Pass
9	0.003	0.073	0.015	0.001	0.000	0.089	#21	0.204	Not Required	Pass
10	0.003	0.608	0.045	0.061	0.010	0.642	#21	0.080	Not Required	Pass
11	0.000	0.062	0.032	0.043	0.005	0.091	#21	0.095	Not Required	Pass
12	0.001	0.441	0.052	0.093	0.009	0.480	#21	0.035	Not Required	Pass
13	0.002	0.225	0.105	0.059	0.007	0.315	#21	0.286	Not Required	Pass
14	0.002	0.209	0.105	0.053	0.007	0.293	#21	0.190	Not Required	Pass
15	0.000	0.076	0.049	0.033	0.004	0.125	#21	Not Required	Not Required	Pass
16	0.000	0.068	0.049	0.030	0.004	0.117	#21	Not Required	Not Required	Pass
101	0.223	0.566	0.004	0.015	0.000	0.683	#13	0.766	Not Required	Pass
102	0.000	0.459	0.053	0.098	0.009	0.499	#21	0.053	Not Required	Pass
103	0.003	0.715	0.022	0.072	0.005	0.739	#21	0.045	Not Required	Pass
104	0.003	0.639	0.040	0.064	0.009	0.671	#21	0.080	Not Required	Pass
105	0.003	0.443	0.039	0.071	0.010	0.452	#21	0.074	Not Required	Pass
106	0.003	0.722	0.024	0.073	0.006	0.747	#21	0.045	Not Required	Pass
107	0.003	0.448	0.039	0.072	0.010	0.457	#21	0.074	Not Required	Pass
108	0.000	0.070	0.028	0.038	0.005	0.099	#21	0.095	Not Required	Pass
109	0.002	0.069	0.015	0.001	0.000	0.084	#21	0.204	Not Required	Pass
110	0.003	0.645	0.038	0.065	0.009	0.674	#21	0.080	Not Required	Pass

110	0.003	0.043	0.036	0.003	0.006	0.074	#21	0.000	Not Required	Pass
111	0.000	0.078	0.028	0.042	0.005	0.106	#21	0.095	Not Required	Pass
112	0.000	0.467	0.053	0.099	0.009	0.506	#21	0.053	Not Required	Pass
113	0.002	0.172	0.095	0.057	0.006	0.245	#21	0.286	Not Required	Pass
114	0.002	0.161	0.095	0.051	0.006	0.230	#21	0.286	Not Required	Pass
115	0.000	0.134	0.053	0.041	0.005	0.187	#21	0.346	Not Required	Pass
116	0.000	0.120	0.054	0.036	0.005	0.174	#21	0.346	Not Required	Pass
201	0.223	0.566	0.004	0.015	0.000	0.683	#13	0.766	Not Required	Pass
202	0.000	0.467	0.053	0.099	0.009	0.506	#21	0.053	Not Required	Pass
203	0.003	0.722	0.024	0.073	0.006	0.747	#21	0.045	Not Required	Pass
204	0.003	0.645	0.038	0.065	0.008	0.674	#21	0.080	Not Required	Pass
205	0.003	0.448	0.039	0.072	0.010	0.457	#21	0.074	Not Required	Pass
206	0.003	0.715	0.022	0.072	0.005	0.739	#21	0.045	Not Required	Pass
207	0.003	0.443	0.039	0.071	0.010	0.452	#21	0.074	Not Required	Pass
208	0.000	0.064	0.032	0.036	0.005	0.091	#21	0.095	Not Required	Pass
209	0.002	0.069	0.015	0.001	0.000	0.084	#21	0.204	Not Required	Pass
210	0.003	0.639	0.040	0.064	0.009	0.671	#21	0.080	Not Required	Pass
211	0.000	0.071	0.032	0.041	0.005	0.098	#21	0.095	Not Required	Pass
212	0.000	0.459	0.053	0.098	0.009	0.499	#21	0.053	Not Required	Pass
213	0.002	0.172	0.095	0.057	0.006	0.245	#21	0.286	Not Required	Pass
214	0.002	0.161	0.095	0.051	0.006	0.230	#21	0.286	Not Required	Pass
215	0.001	0.148	0.053	0.042	0.005	0.201	#21	0.346	Not Required	Pass
216	0.000	0.133	0.053	0.038	0.005	0.187	#21	0.346	Not Required	Pass
301	0.214	0.558	0.008	0.015	0.000	0.632	#13	0.766	Not Required	Pass
302	0.001	0.441	0.052	0.093	0.009	0.480	#21	0.035	Not Required	Pass
303	0.003	0.683	0.021	0.069	0.004	0.704	#21	0.045	Not Required	Pass
304	0.003	0.608	0.045	0.061	0.010	0.642	#21	0.080	Not Required	Pass
305	0.003	0.424	0.044	0.068	0.011	0.434	#21	0.074	Not Required	Pass
306	0.003	0.696	0.021	0.070	0.004	0.718	#21	0.045	Not Required	Pass
307	0.003	0.431	0.043	0.069	0.011	0.441	#21	0.115	Not Required	Pass
308	0.000	0.068	0.049	0.030	0.004	0.117	#21	Not Required	Not Required	Pass
309	0.003	0.073	0.015	0.001	0.000	0.089	#21	0.204	Not Required	Pass
310	0.003	0.622	0.040	0.063	0.009	0.650	#21	0.123	Not Required	Pass
311	0.000	0.076	0.049	0.033	0.004	0.125	#21	Not Required	Not Required	Pass
312	0.001	0.456	0.053	0.095	0.009	0.497	#21	0.053	Not Required	Pass
313	0.002	0.225	0.105	0.059	0.007	0.315	#21	0.190	Not Required	Pass
314	0.002	0.209	0.105	0.053	0.007	0.293	#21	0.286	Not Required	Pass
315	0.000	0.130	0.053	0.043	0.005	0.183	#21	0.346	Not Required	Pass
316	0.000	0.117	0.053	0.039	0.005	0.170	#21	0.346	Not Required	Pass

## Definitions

$\Phi_t$	Safety factor for tensile
$\Phi_c$	Safety factor for compression
$\Phi_b$	Safety factor for flexure
$\Phi_v$	Safety factor for shear
E	Modulus of elasticity
$F_y$	Specified minimum yield stress
$F_u$	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
$I_{yp}$	Moment of inertia about the Y axes
$I_{zp}$	Moment of inertia about the Z axes
$I_w$	Warping constant
$S_{yp}$	Plastic section modulus about the Y axis

$S_{zp}$	Plastic section modulus about the Z axis
KL	Effective length
$C_b$	Buckling modification factor (from all load combinations)
$L_b$	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
$P_n$	Nominal axial strength (tension/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
$\delta$	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided



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

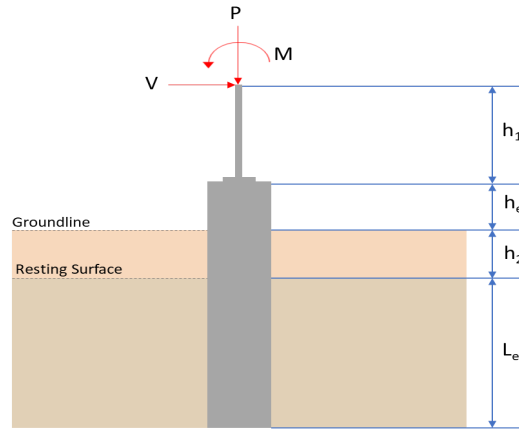
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: round

$D = 36$  in - Pile diameter

$L = 7.75$  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)	7.666	11.508
$V_x$ (kip)	-0.654	-1.093
$V_z$ (kip)	-0.024	-0.037
$M_x$ (kipft)	-0.106	-0.165
$M_z$ (kipft)	13.292	23.587

### 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,

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

$$H_o = \frac{(-0.654 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.218 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(13.292 \text{ kipft}) + ((-0.654 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 4.4307 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.3973 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.024 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.008 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((-0.024 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.035333 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.4911 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.3973 \text{ ft}), (1.4911 \text{ ft})]$$

$$L_{e,req} = 7.397 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$Ratio = \frac{(7.397 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.95445$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.666 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.0845 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.0845 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.54226$$

Status: **PASS**  
Ratio: **0.540**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.218 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.4307 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.4307 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (4.4307 \text{ kipft/ft})) + (4 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2976 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.4307 \text{ kipft/ft})) + (3 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (4.4307 \text{ kipft/ft})) + (2 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.31681 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (4.4307 \text{ kipft/ft})) + ((-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1254 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2976 \text{ ft})}{2}$$

$$p_a = 0.39732 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31681 \text{ kip/ft}^2)}{(0.39732 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.79738$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1254 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.96809$$

Status: **PASS**  
Ratio: **0.800**

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

**Considering z-direction:**

$H_o = -0.008 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.035333 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.035333 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.008 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.035333 \text{ kipft/ft})) + (4 \times (-0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5149 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.035333 \text{ kipft/ft})) + (3 \times (-0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.035333 \text{ kipft/ft})) + (2 \times (-0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = -0.0021739 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.035333 \text{ kipft/ft})) + ((-0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 0.00136 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5149 \text{ ft})}{2}$$

$$p_a = 0.41361 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0021739 \text{ kip/ft}^2)}{(0.41361 \text{ kip/ft}^2)}$$

$$(0.00136 \text{ kip/ft}^2)$$

$$\text{Ratio} = -0.0052558$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

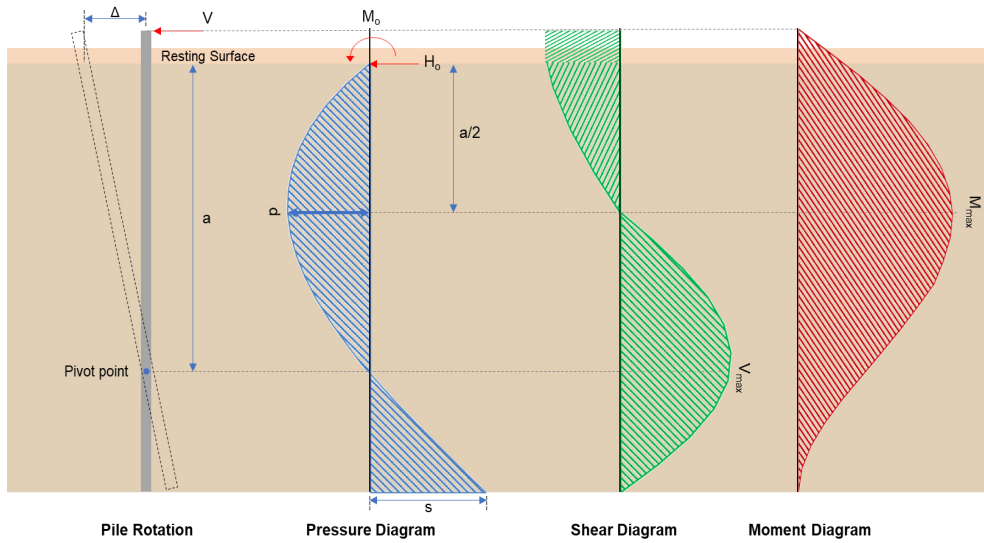
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(0.00136 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.0011699$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.093 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.36433 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.587 \text{ kipft}) + ((-1.093 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.8623 \text{ kipft/ft}$$

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

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

$$E = \frac{(7.8623 \text{ kipft/ft})}{(-0.36433 \text{ kip/ft})}$$

$$E = 21.58 \text{ ft}$$

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

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

$$a = \frac{(4 \times (7.8623 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.36433 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (7.8623 \text{ kipft/ft})) + (4 \times (-0.36433 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2914 \text{ ft}$$

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

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

$$V_{max} = ((-0.36433 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2914 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2914 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.1106 \text{ kip}$$

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

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

$$M_{max} = ((-0.36433 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(21.58 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 22.905 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.037 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.012333 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.165 \text{ kipft}) + ((-0.037 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.055 \text{ kipft/ft})}{(-0.012333 \text{ kip/ft})}$$

$$E = 4.4595 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.055 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.012333 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.055 \text{ kipft/ft})) + (4 \times (-0.012333 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5133 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((-0.012333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5133 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5133 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.062274 \text{ kip}$$

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

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

$$M_{max} = ((-0.012333 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(4.4595 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.21568 \text{ kipft}$$

### 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,

$\alpha = 0.85$  - Alpha factor for axial strength,

$A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(11.508 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37.014 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$(1.8322 \text{ in}^2)$$

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;"><math>Ratio = \frac{\lambda}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>1.000</b></p>
<p>22.4.2.2</p>	<p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.508 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0091777</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width, <math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p>	

$$V_{c,max} = 186.09 \text{ kip}$$

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.508 \text{ kip} \rightarrow 11508 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11508 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.392 \text{ kip}$$

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)

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

$$V_{c,b} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.392 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.392 \text{ kip}$$

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

$A_v$  - 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)

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

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$  - Governing shear strength of steel

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

$$V_s = \text{MIN}[(414.72 \text{ kip}), (38.17 \text{ kip})]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.392 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.465 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 6.1106 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(6.1106 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.08206$$

Status: **PASS**  
Ratio: **0.080**

**Considering z-direction:**

$V_{max} = 0.062274 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.062274 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.00083628$$

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

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

$S_m$  - Section modulus

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

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 4580.442 \text{ in}^3$$

$$\phi M_{n,1} = 62.027 \text{ kipft}$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$$

$$\phi M_{n,2} = 527.23 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$

$$\phi M_n = 62.027 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 22.905 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(22.905 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.36928$$

Status: **PASS**  
Ratio: **0.370**

**Considering z-direction:**

$M_{max} = 0.21568 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(0.21568 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0034773$$

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

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

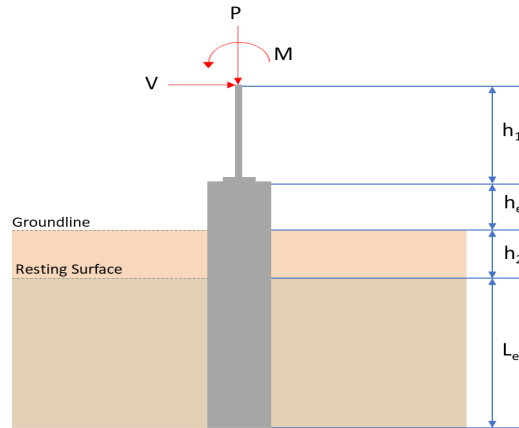
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: round

$D = 36$  in - Pile diameter

$L = 7.75$  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)	7.976	11.982
$V_x$ (kip)	-0.659	-1.100
$V_z$ (kip)	0.012	0.018
$M_x$ (kipft)	0.052	0.078
$M_z$ (kipft)	13.453	23.921

### 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,

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

$$H_o = \frac{(-0.659 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.21967 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(13.453 \text{ kipft}) + ((-0.659 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 4.4843 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.4273 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.012 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.004 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.052 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.017333 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.393 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(7.4273 \text{ ft}), (1.393 \text{ ft})]$$

$$L_{e,req} = 7.427 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.427 \text{ ft})}{(7.75 \text{ ft})}$$

$$\text{Ratio} = 0.95832$$

Status: **PASS**  
Ratio: **0.960**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.976 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1284 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.1284 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.56419$$

Status: **PASS**  
Ratio: **0.560**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.21967 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.4843 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.4843 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (4.4843 \text{ kipft/ft})) + (4 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2971 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.4843 \text{ kipft/ft})) + (3 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (4.4843 \text{ kipft/ft})) + (2 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.3213 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (4.4843 \text{ kipft/ft})) + ((-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1402 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2971 \text{ ft})}{2}$$

$$p_a = 0.39728 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.3213 \text{ kip/ft}^2)}{(0.39728 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.80875$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1402 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.98083$$

Status: **PASS**  
Ratio: **0.810**

Status: **PASS**  
Ratio: **0.980**

**Considering z-direction:**

$H_o = 0.004 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.017333 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.017333 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.004 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.017333 \text{ kipft/ft})) + (4 \times (0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5179 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.017333 \text{ kipft/ft})) + (3 \times (0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.017333 \text{ kipft/ft})) + (2 \times (0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.0045337 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.017333 \text{ kipft/ft})) + ((0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 0.010304 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5179 \text{ ft})}{2}$$

$$p_a = 0.41384 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0045337 \text{ kip/ft}^2)}{(0.41384 \text{ kip/ft}^2)}$$

(0.010304 kip/ft<sup>2</sup>)

$$Ratio = 0.010955$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

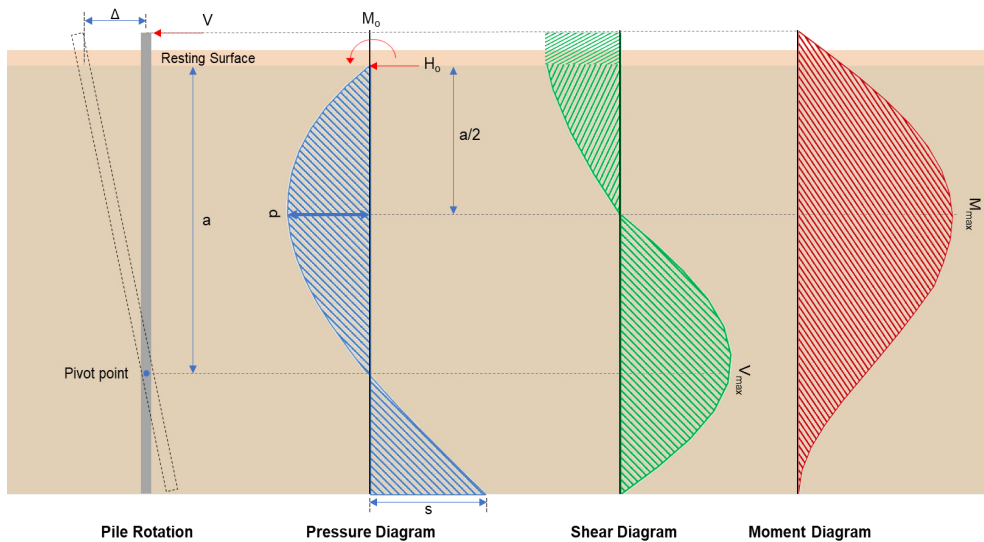
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.010304 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$Ratio = 0.008864$$

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,

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

$$H_o = \frac{(-1.1 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.36667 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.921 \text{ kipft}) + ((-1.1 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.9737 \text{ kipft/ft}$$

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

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

$$E = \frac{(7.9737 \text{ kipft/ft})}{(-0.36667 \text{ kip/ft})}$$

$$E = 21.746 \text{ ft}$$

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

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

$$a = \frac{(4 \times (7.9737 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.36667 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (7.9737 \text{ kipft/ft})) + (4 \times (-0.36667 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2907 \text{ ft}$$

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

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

$$V_{max} = ((-0.36667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2907 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2907 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.1917 \text{ kip}$$

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

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

$$M_{max} = ((-0.36667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(21.746 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 23.214 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.018 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.006 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.078 \text{ kipft}) + ((0.018 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.026 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.026 \text{ kipft/ft})}{(0.006 \text{ kip/ft})}$$

$$E = 4.3333 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.026 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.006 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.026 \text{ kipft/ft})) + (4 \times (0.006 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5179 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((0.006 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5179 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5179 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.029782 \text{ kip}$$

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

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

$$M_{max} = ((0.006 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(4.3333 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.10294 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

$f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,

$\phi = 0.65$  - Reduction factor for axial strength,

Table 22.4.2.1

$\alpha = 0.85$  - Alpha factor for axial strength,

$A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(11.982 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$= \frac{1.8322 \text{ in}^2}{1.8408 \text{ in}^2}$$

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = \frac{\lambda}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>1.000</b></p>
<p>22.4.2.2</p>	<p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.982 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0095557</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width, <math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p>	

$$V_{c,max} = 186.09 \text{ kip}$$

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.982 \text{ kip} \rightarrow 11982 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11982 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.472 \text{ kip}$$

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)

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

$$V_{c,b} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.472 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.472 \text{ kip}$$

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

$A_v$  - 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)

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

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$  - Governing shear strength of steel

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

$$V_s = \text{MIN}[(414.72 \text{ kip}), (38.17 \text{ kip})]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.472 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.518 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 6.1917 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(6.1917 \text{ kip})}{(74.518 \text{ kip})}$$

$$Ratio = 0.08309$$

Status: **PASS**  
Ratio: **0.080**

**Considering z-direction:**

$V_{max} = 0.029782 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.029782 \text{ kip})}{(74.518 \text{ kip})}$$

$$Ratio = 0.00039966$$

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

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

$S_m$  - Section modulus

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

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 4580.442 \text{ in}^3$$

$$\phi M_{n,1} = 62.027 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$$

$$\phi M_{n,2} = 527.23 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$

$$\phi M_n = 62.027 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 23.214 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(23.214 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.37426$$

Status: **PASS**  
Ratio: **0.370**

**Considering z-direction:**

$M_{max} = 0.10294 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{M_u}{\phi M_n}$$

$$Ratio = \frac{(0.10294 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0016597$$

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

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

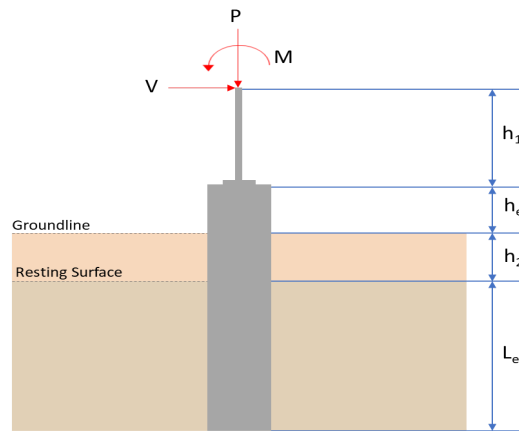
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: round

$D = 36$  in - Pile diameter

$L = 7.75$  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)	7.976	11.982
$V_x$ (kip)	-0.659	-1.100
$V_z$ (kip)	-0.012	-0.018
$M_x$ (kipft)	-0.052	-0.078
$M_z$ (kipft)	13.453	23.921

### 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,

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

$$H_o = \frac{(-0.659 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.21967 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(13.453 \text{ kipft}) + ((-0.659 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 4.4843 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.4273 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.012 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.004 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.052 \text{ kipft}) + ((-0.012 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.017333 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.1994 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(7.4273 \text{ ft}), (1.1994 \text{ ft})]$$

$$L_{e,req} = 7.427 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$Ratio = \frac{(7.427 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.95832$$

Status: **PASS**  
Ratio: **0.960**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.976 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1284 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.1284 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.56419$$

Status: **PASS**  
Ratio: **0.560**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.21967 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.4843 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.4843 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (4.4843 \text{ kipft/ft})) + (4 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2971 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.4843 \text{ kipft/ft})) + (3 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (4.4843 \text{ kipft/ft})) + (2 \times (-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.3213 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (4.4843 \text{ kipft/ft})) + ((-0.21967 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1402 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2971 \text{ ft})}{2}$$

$$p_a = 0.39728 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.3213 \text{ kip/ft}^2)}{(0.39728 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.80875$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1402 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.98083$$

Status: **PASS**  
Ratio: **0.810**

Status: **PASS**  
Ratio: **0.980**

**Considering z-direction:**

$H_o = -0.004 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.017333 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.017333 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.004 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.017333 \text{ kipft/ft})) + (4 \times (-0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5179 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.017333 \text{ kipft/ft})) + (3 \times (-0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.017333 \text{ kipft/ft})) + (2 \times (-0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = -0.0010985 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.017333 \text{ kipft/ft})) + ((-0.004 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 0.00057537 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5179 \text{ ft})}{2}$$

$$p_a = 0.41384 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0010985 \text{ kip/ft}^2)}{(0.41384 \text{ kip/ft}^2)}$$

(0.0007537 kip/ft<sup>2</sup>)

$$Ratio = -0.0026545$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

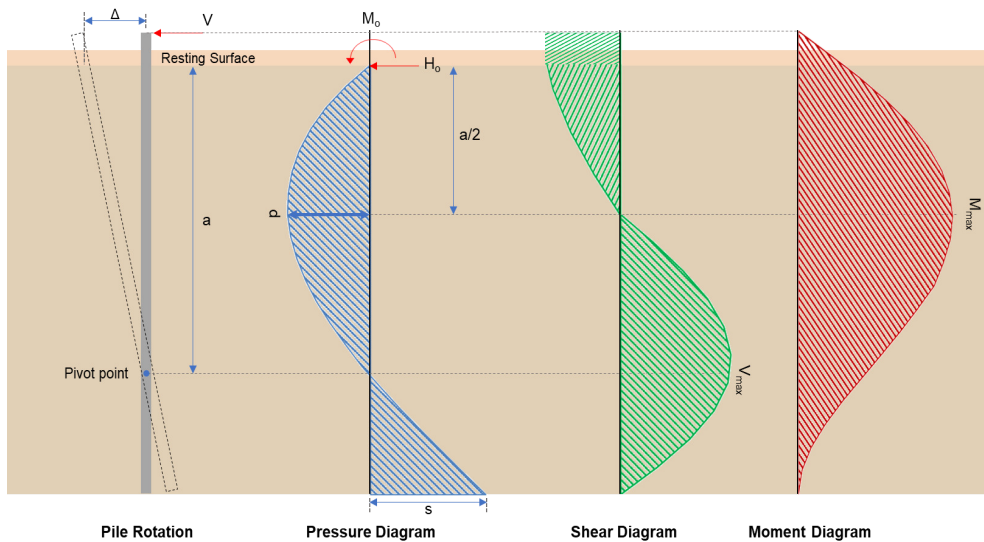
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0007537 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$Ratio = 0.00049494$$

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,

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

$$H_o = \frac{(-1.1 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.36667 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.921 \text{ kipft}) + ((-1.1 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.9737 \text{ kipft/ft}$$

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

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

$$E = \frac{(7.9737 \text{ kipft/ft})}{(-0.36667 \text{ kip/ft})}$$

$$E = 21.746 \text{ ft}$$

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

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

$$a = \frac{(4 \times (7.9737 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.36667 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (7.9737 \text{ kipft/ft})) + (4 \times (-0.36667 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2907 \text{ ft}$$

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

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

$$V_{max} = ((-0.36667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2907 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2907 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.1917 \text{ kip}$$

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

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

$$M_{max} = ((-0.36667 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(21.746 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (21.746 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2907 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 23.214 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.006 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.078 \text{ kipft}) + ((-0.018 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.026 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.026 \text{ kipft/ft})}{(-0.006 \text{ kip/ft})}$$

$$E = 4.3333 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.026 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.006 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.026 \text{ kipft/ft})) + (4 \times (-0.006 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5179 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = ((-0.006 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5179 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5179 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.029782 \text{ kip}$$

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

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

$$M_{max} = ((-0.006 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(4.3333 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.3333 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5179 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.10294 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

$f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,

$\phi = 0.65$  - Reduction factor for axial strength,

Table 22.4.2.1

$\alpha = 0.85$  - Alpha factor for axial strength,

$A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\left( \frac{11.982 \text{ kip}}{(0.65) \times (0.85)} \right) - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$= \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = \frac{\quad}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>1.000</b></p>
<p>22.4.2.2</p>	<p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.982 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0095557</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width, <math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p>	

$$V_{c,max} = 186.09 \text{ kip}$$

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.982 \text{ kip} \rightarrow 11982 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11982 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.472 \text{ kip}$$

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)

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

$$V_{c,b} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.472 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.472 \text{ kip}$$

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

$A_v$  - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$  - Governing shear strength of steel

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

$$V_s = \text{MIN}[(414.72 \text{ kip}), (38.17 \text{ kip})]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.472 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.518 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 6.1917 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(6.1917 \text{ kip})}{(74.518 \text{ kip})}$$

$$Ratio = 0.08309$$

Status: **PASS**  
Ratio: **0.080**

**Considering z-direction:**

$V_{max} = 0.029782 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.029782 \text{ kip})}{(74.518 \text{ kip})}$$

$$Ratio = 0.00039966$$

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

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

$S_m$  - Section modulus

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

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 4580.442 \text{ in}^3$$

$$\phi M_{n,1} = 62.027 \text{ kipft}$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$$

$$\phi M_{n,2} = 527.23 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$

$$\phi M_n = 62.027 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 23.214 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(23.214 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.37426$$

Status: **PASS**  
Ratio: **0.370**

**Considering z-direction:**

$M_{max} = 0.10294 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

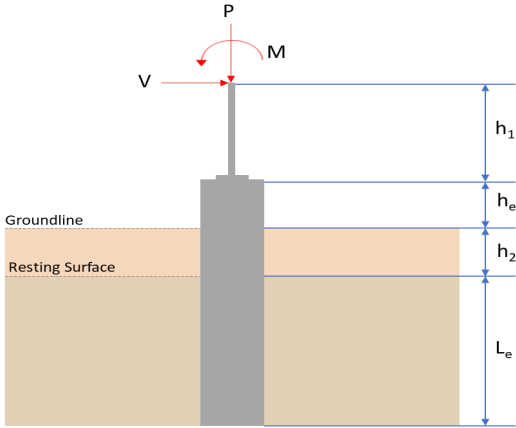
$$Ratio = \frac{M_{max}}{\phi M_n}$$

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(0.10294 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0016597$$

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

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b></p> <p>Pile shape: round  <math>D = 36</math> in - Pile diameter  <math>L = 7.75</math> ft - Total pile length  <math>h_1 = 0</math> ft - Lateral load height from the top of the pile,  <math>h_2 = 0</math> ft - Depth to resisting surface  <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1" data-bbox="368 1061 1227 1162"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1" data-bbox="655 1267 940 1456"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>7.666</td> <td>11.508</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-0.654</td> <td>-1.093</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.024</td> <td>0.037</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.106</td> <td>0.165</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>13.292</td> <td>23.587</td> </tr> </tbody> </table> <p><b>Material Properties</b></p> <p><math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	7.666	11.508	$V_x$ (kip)	-0.654	-1.093	$V_z$ (kip)	0.024	0.037	$M_x$ (kipft)	0.106	0.165	$M_z$ (kipft)	13.292	23.587	
Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)																									
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																									
Load Component	ASD	LRFD																										
$P$ (kip)	7.666	11.508																										
$V_x$ (kip)	-0.654	-1.093																										
$V_z$ (kip)	0.024	0.037																										
$M_x$ (kipft)	0.106	0.165																										
$M_z$ (kipft)	13.292	23.587																										
	<p><b>Required depth to resist lateral loads (ASD)</b></p> <p><math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-0.654 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.218 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p>																											

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

$$M_o = \frac{(13.292 \text{ kipft}) + ((-0.654 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 4.4307 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.3973 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.024 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.008 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((0.024 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.035333 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.7961 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(7.3973 \text{ ft}), (1.7961 \text{ ft})]$$

$$L_{e,req} = 7.397 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.397 \text{ ft})}{(7.75 \text{ ft})}$$

$$\text{Ratio} = 0.95445$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.666 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.0845 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.0845 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.54226$$

Status: **PASS**  
Ratio: **0.540**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(7.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.218 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.4307 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.4307 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (4.4307 \text{ kipft/ft})) + (4 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2976 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (4.4307 \text{ kipft/ft})) + (3 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (4.4307 \text{ kipft/ft})) + (2 \times (-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.31681 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (4.4307 \text{ kipft/ft})) + ((-0.218 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1254 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2976 \text{ ft})}{2}$$

$$p_a = 0.39732 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31681 \text{ kip/ft}^2)}{(0.39732 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.79738$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1254 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.96809$$

Status: **PASS**  
Ratio: **0.800**

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

**Considering z-direction:**

$H_o = 0.008 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.035333 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.035333 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.008 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.035333 \text{ kipft/ft})) + (4 \times (0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5149 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.035333 \text{ kipft/ft})) + (3 \times (0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.035333 \text{ kipft/ft})) + (2 \times (0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.0091368 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.035333 \text{ kipft/ft})) + ((0.008 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 0.020818 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5149 \text{ ft})}{2}$$

$$p_a = 0.41361 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0091368 \text{ kip/ft}^2)}{(0.41361 \text{ kip/ft}^2)}$$

(0.020818 kip/ft<sup>2</sup>)

$$Ratio = 0.02209$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

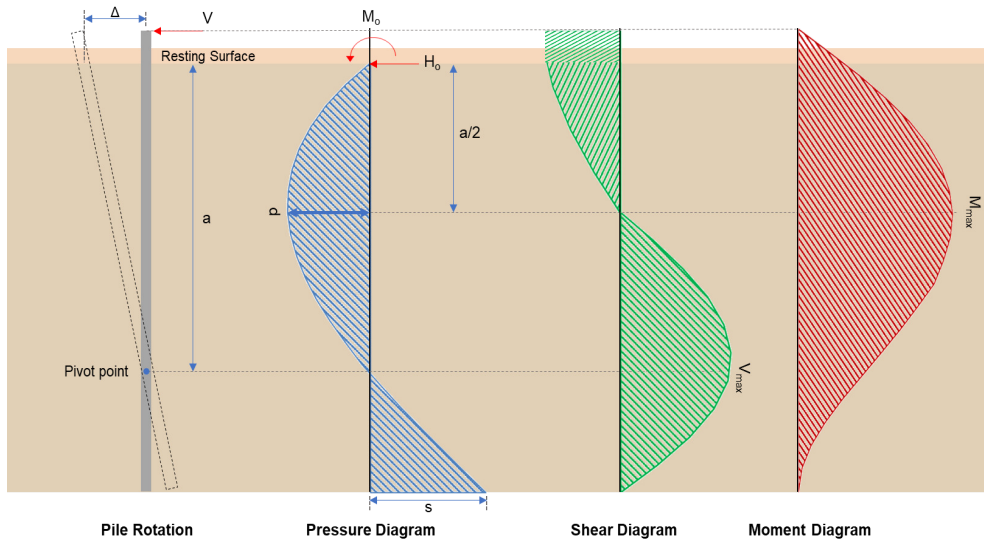
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.020818 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$Ratio = 0.017908$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.093 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.36433 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.587 \text{ kipft}) + ((-1.093 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.8623 \text{ kipft/ft}$$

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

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

$$E = \frac{(7.8623 \text{ kipft/ft})}{(-0.36433 \text{ kip/ft})}$$

$$E = 21.58 \text{ ft}$$

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

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

$$a = \frac{(4 \times (7.8623 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.36433 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (7.8623 \text{ kipft/ft})) + (4 \times (-0.36433 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.2914 \text{ ft}$$

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

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

$$V_{max} = ((-0.36433 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2914 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2914 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.1106 \text{ kip}$$

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

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

$$M_{max} = ((-0.36433 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(21.58 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (21.58 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.2914 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 22.905 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.037 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.012333 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.165 \text{ kipft}) + ((0.037 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.055 \text{ kipft/ft})}{(0.012333 \text{ kip/ft})}$$

$$E = 4.4595 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.055 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.012333 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.055 \text{ kipft/ft})) + (4 \times (0.012333 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5133 \text{ ft}$$

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

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

$$\left[ \frac{L_e}{L_e} \right]$$

$$V_{max} = \left( (0.012333 \text{ kip/ft}) \times (36 \text{ in}) \right) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5133 \text{ ft})}{(7.75 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5133 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.062274 \text{ kip}$$

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

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

$$M_{max} = \left( (0.012333 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft}) \right) \times \left[ \left( \frac{(4.4595 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.4595 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.5133 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.21568 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

$f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,

$\phi = 0.65$  - Reduction factor for axial strength,

Table 22.4.2.1

$\alpha = 0.85$  - Alpha factor for axial strength,

$A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(11.508 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-37.014 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

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

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$(1.8322 \text{ in}^2)$$

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = \frac{\quad}{(1.8408 \text{ in}^2)}</math></p> <p style="text-align: center;"><math>Ratio = 0.99533</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 d_{bar})]</math></p> <p><math>s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]</math></p> <p style="text-align: center;"><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p><math>s_{ties} = Max [16 d_{bar}, (48 d_{ties}), D]</math></p> <p><math>s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]</math></p> <p style="text-align: center;"><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>6 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>1.000</b></p>
<p>22.4.2.2</p>	<p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p><math>\phi P_N</math> - Allowable axial compressive strength</p> <p style="text-align: center;"><math>\phi P_N = \phi 0.85 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 1253.9 \text{ kip}</math></p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(11.508 \text{ kip})}{(1253.9 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0091777</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 36 \text{ in}</math> - Effective width, <math>d</math> - Effective depth</p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (36 \text{ in})</math></p> <p style="text-align: center;"><math>d = 28.8 \text{ in}</math></p> <p><math>\lambda_s</math> - size effect modification factor</p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.71796</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{c,max}</math> - Max shear strength of concrete</p> <p style="text-align: center;"><math>V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d</math></p> <p style="text-align: center;"><math>V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})</math></p>	

$$V_{c,max} = 186.09 \text{ kip}$$

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 11.508 \text{ kip} \rightarrow 11508 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11508 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.392 \text{ kip}$$

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)

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

$$V_{c,b} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.392 \text{ kip}), (204.04 \text{ kip})]$$

$$V_c = 76.392 \text{ kip}$$

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

$A_v$  - 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)

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

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

$V_s$  - Governing shear strength of steel

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

$$V_s = \text{MIN}[(414.72 \text{ kip}), (38.17 \text{ kip})]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.392 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.465 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 6.1106 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(6.1106 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.08206$$

Status: **PASS**  
Ratio: **0.080**

**Considering z-direction:**

$V_{max} = 0.062274 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.062274 \text{ kip})}{(74.465 \text{ kip})}$$

$$Ratio = 0.00083628$$

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

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

$S_m$  - Section modulus

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

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 4580.442 \text{ in}^3$$

$$\phi M_{n,1} = 62.027 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$$

$$\phi M_{n,2} = 527.23 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$

$$\phi M_n = 62.027 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 22.905 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(22.905 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.36928$$

Status: **PASS**  
Ratio: **0.370**

**Considering z-direction:**

$M_{max} = 0.21568 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$ratio = \frac{1}{\phi M_n}$$

$$Ratio = \frac{(0.21568 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.0034773$$

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