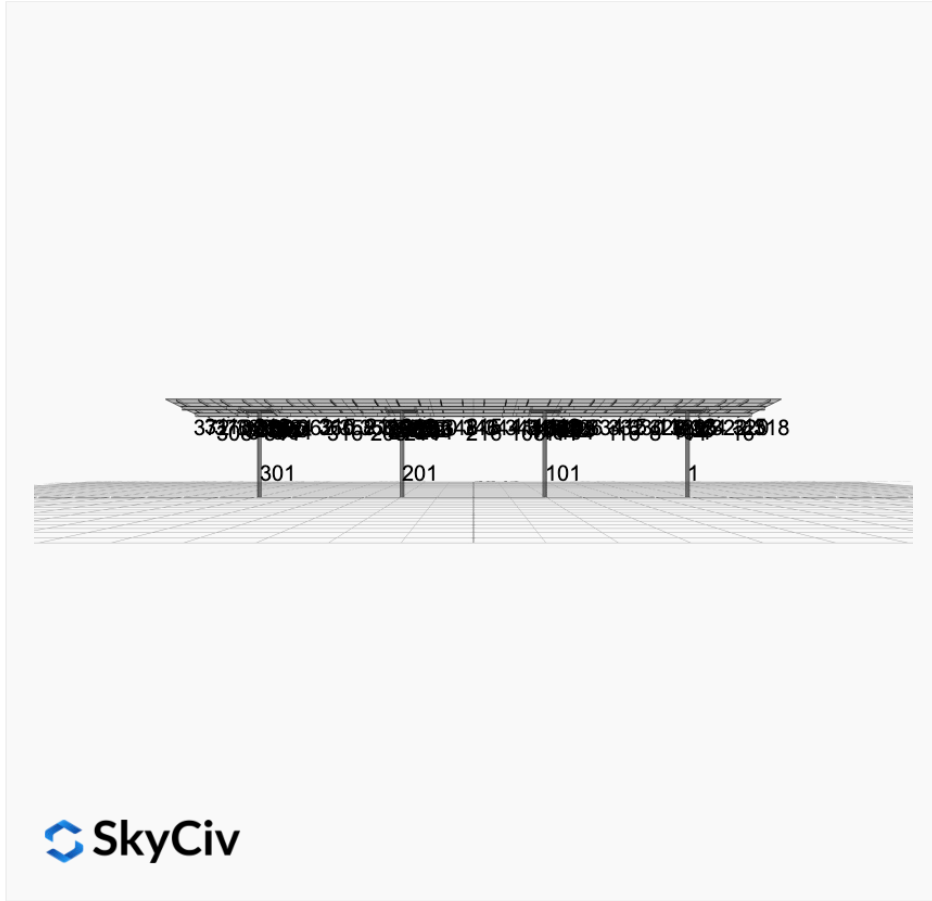


# Project Details



**Project Name:** Mulawa 5x14 - V1Jb  
**Location:** 4921 W Paseo De Las Colinas, Tucson, AZ 85745, USA  
**Unique ID:** 4P-19.75-6TOP-SD-72-L-5Hx14W-2CCC  
**Dealer:** \_\_\_\_\_

**Date:** Fri Apr 11 2025  
**Number of Modules:** 70  
**Number of Poles:** 4  
**Date Sold:** \_\_\_\_\_



<b>Array Dimensions N/S</b>	18.81 ft
<b>Array Dimensions E/W</b>	80.27 ft
<b>Winter Tilt Angle</b>	5
<b>Front Edge Clearance</b>	11 ft

## MT Solar Bill of Materials (4P-19.75-6TOP-SD-72-L-5Hx14W-2CCC)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	4
MTS-HF-SD	H-Frame Assembly-SD	4
MTS-SD-Wing-72	72IN SD Wing	4
MTS-SD-Splice-90	90IN SD Splice	6
MTS-SD-Splice-57	57IN SD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	14

## Rail Bill of Materials

Part	Qty
Rails (226in)	28
Rail Attachment	112

<b>Part</b>	<b>Qty</b>
Module Mid Clamp	112
Module End Clamp	56
Ground Lug	14

## Site Details:



**Site Address:** 4921 W Paseo De Las Colinas, Tucson, AZ 85745, USA

### Array Specification

<b>Duty Classification:</b>	SD
<b>Module Width:</b>	44.65 in
<b>Module Length:</b>	67.80in
<b>Number of Rows:</b>	5
<b>Number of Columns:</b>	14
<b>Total Number of Modules:</b>	70
<b>Winter Tilt Angle:</b>	5
<b>Front Edge Clearance:</b>	11
<b>Total Array Height at Tilt:</b>	12.64 ft
<b>Total Frame Length:</b>	78.75 ft
<b>Module Info/Notes:</b>	
<b>Array Dimensions N/S:</b>	18.81 ft
<b>Array Dimensions E/W:</b>	80.27 ft
<b>Rail Length:</b>	225.75 in
<b>Rail Spacing:</b>	2.87 ft

### Support Specifications

<b>Pole Size:</b>	6in Pipe Sch 40
<b>Pole Length above Grade:</b>	11.82 ft
<b>Number of Poles:</b>	4
<b>Pole Spacing:</b>	19.75 ft

### Foundation Specifications

<b>Foundation Type:</b>	Square
<b>Foundation Dimensions:</b>	48 x 48 in
<b>Foundation Depth (below grade):</b>	Pile 1: 4.25 ft Pile 2: 4.00 ft Pile 3: 4.00 ft Pile 4: 4.25 ft
<b>Foundation Volume:</b>	9.778 y <sup>3</sup>

### Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	B
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	4921 W Paseo De Las Colinas, Tucson, AZ 85745, USA
<b>Wind Speed:</b>	90 mph

**Snow Load:**

0 psf

### **Design Disclaimer**

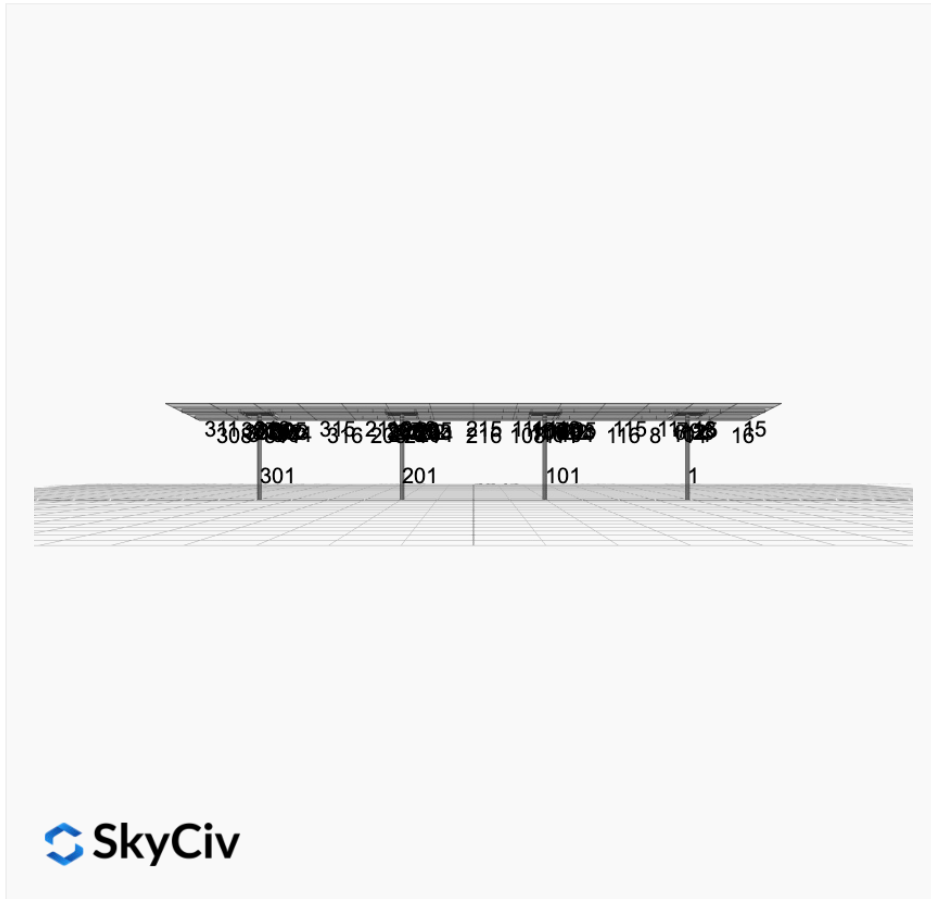
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

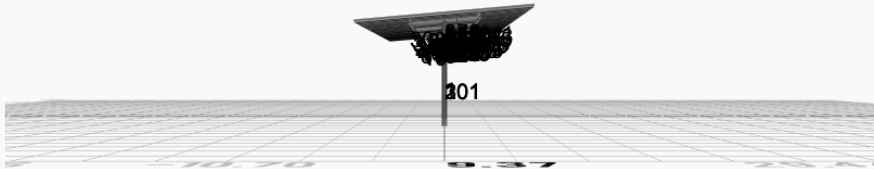
## AutoDesigner Input

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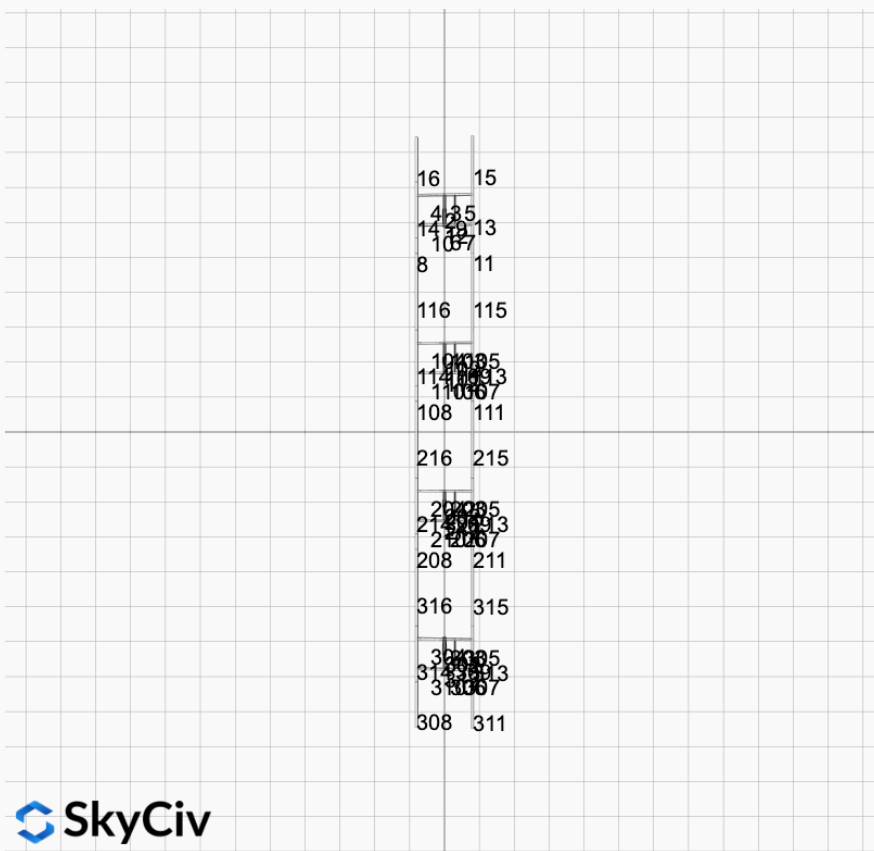
## Design Notes:

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





 SkyCiv

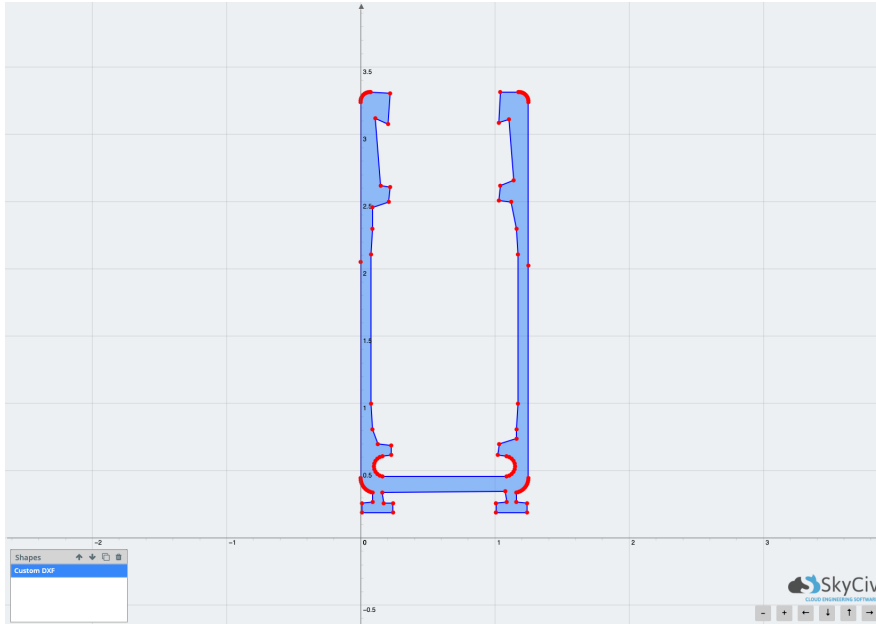


 SkyCiv



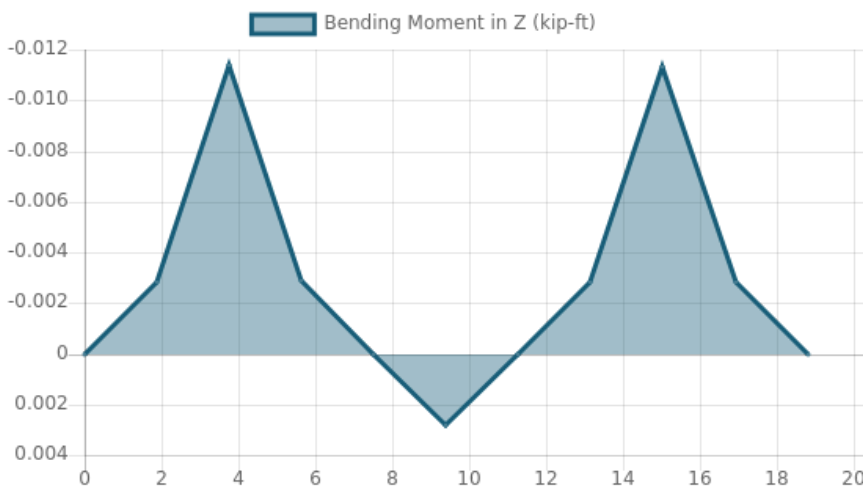
## Rail Design Check

**Rail Length:** 18.8125 ft  
**Additional Restraints Required:** 4ft Spread Clamps  
**Tributary Width:** 2.866666666666667 ft  
**Material:** Aluminium  
**Density:** 169 lb/ft<sup>3</sup>  
**Elasticity Modulus:** 10000 ksi  
**Fy:** 34.5 ksi  
**Fu:** 37 ksi  
**Wind uplift Case A (X):** 0.0000 kip/ft  
**Wind uplift Case A (Y):** 0.0128 kip/ft  
**Wind uplift Case A:** 0.0000 kip/ft  
**Wind uplift Case B:** 0.0000 kip/ft  
**Wind uplift Case B (X):** 0.0000 kip/ft  
**Wind uplift Case B (Y):** 0.0294 kip/ft

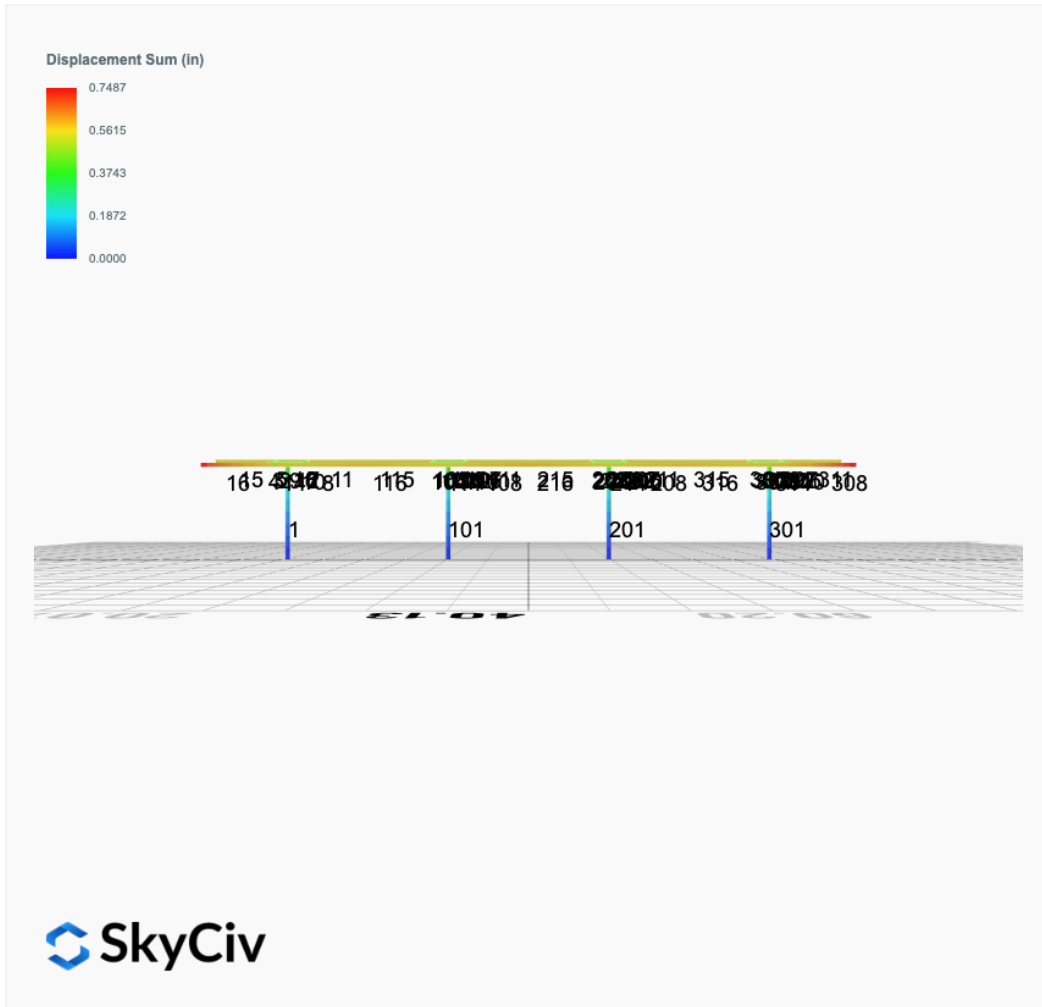


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	4.4296582	0.128	PASS
Material Yield	34.5	4.4296582	0.128	PASS
Material Strength	37	4.4296582	0.120	PASS

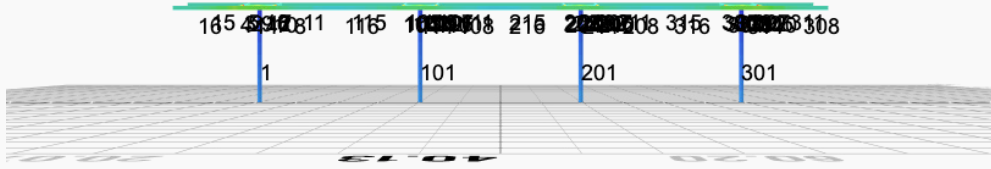
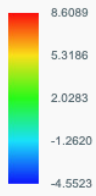
Member 1, ULS: 1. 1.4D



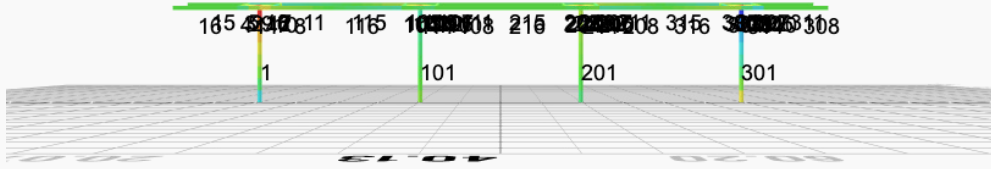
# FEM Results (Envelope Worst Case for each member)



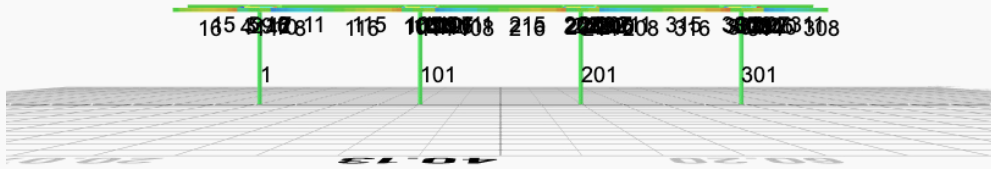
Top Bending Stress Z (ksi)



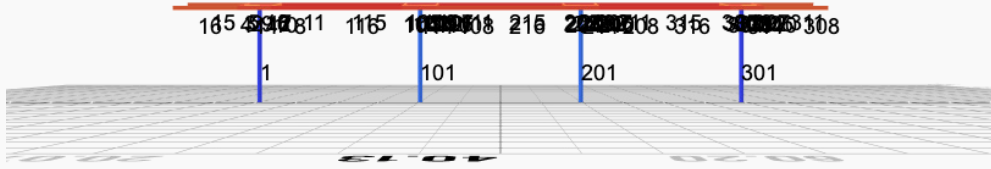
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 2. D + L	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 3. D + (S or Lr or R)	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 3. D + (S or Lr or R)	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 5b. D + 0.7E	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0037	2.5015	-0.0664	-0.2462	0.0156	0.0610
ULS: 8. 0.6D + 0.7E	-0.0022	1.5009	-0.0399	-0.1477	0.0094	0.0366
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.1700	4.4167	-0.1265	-0.4688	0.0337	2.4304
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.1700	4.4167	-0.1265	-0.4688	0.0337	2.4304
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0425	1.9845	-0.0506	-0.1877	0.0116	1.4318
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0993	1.2858	-0.0277	-0.1033	0.0025	-5.3491
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1285	3.9379	-0.1115	-0.4131	0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1285	3.9379	-0.1115	-0.4131	0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0310	2.1138	-0.0546	-0.2023	0.0126	1.0891
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0736	1.5897	-0.0374	-0.1390	0.0058	-3.9966
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1285	3.9379	-0.1115	-0.4131	0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1285	3.9379	-0.1115	-0.4131	0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0310	2.1138	-0.0546	-0.2023	0.0126	1.0891
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0736	1.5897	-0.0374	-0.1390	0.0058	-3.9966
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.1686	3.4161	-0.0999	-0.3703	0.0275	2.4060
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.1686	3.4161	-0.0999	-0.3703	0.0275	2.4060
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0440	0.9839	-0.0240	-0.0892	0.0054	1.4074
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1008	0.2852	-0.0011	-0.0048	-0.0037	-5.3735

### 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	6.1939
Shear X	-0.2815
Shear Z	-0.1802
Moment X	-0.6696
Moment Y (Twist)	0.0491
Moment Z	9.2529

### 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	4.4167
Shear X	-0.1700
Shear Z	-0.1265
Moment X	-0.4688
Moment Y (Twist)	0.0337
Moment Z	5.3735

## 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	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 2. D + L	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 3. D + (S or Lr or R)	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 3. D + (S or Lr or R)	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 5b. D + 0.7E	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0037	2.4020	0.0158	0.0590	-0.0040	-0.0173
ULS: 8. 0.6D + 0.7E	0.0022	1.4412	0.0095	0.0354	-0.0024	-0.0104
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.1572	4.2271	0.0301	0.1125	-0.0074	2.2804
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.1572	4.2271	0.0301	0.1125	-0.0074	2.2804
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0458	1.9097	0.0119	0.0444	-0.0023	1.3356
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1084	1.2429	0.0069	0.0258	-0.0033	-5.3133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1170	3.7708	0.0266	0.0992	-0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1170	3.7708	0.0266	0.0992	-0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0353	2.0328	0.0129	0.0480	-0.0028	0.9974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0823	1.5327	0.0091	0.0341	-0.0035	-3.9893
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1170	3.7708	0.0266	0.0992	-0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1170	3.7708	0.0266	0.0992	-0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0353	2.0328	0.0129	0.0480	-0.0028	0.9974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0823	1.5327	0.0091	0.0341	-0.0035	-3.9893
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.1587	3.2663	0.0238	0.0889	-0.0058	2.2874
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.1587	3.2663	0.0238	0.0889	-0.0058	2.2874
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0443	0.9489	0.0055	0.0208	-0.0007	1.3425
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1069	0.2821	0.0006	0.0022	-0.0017	-5.3064

### 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	5.9241
Shear X	-0.2682
Shear Z	0.0429
Moment X	0.1607
Moment Y (Twist)	0.0104
Moment Z	9.1457

### 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	4.2271
Shear X	-0.1587
Shear Z	0.0301
Moment X	0.1125
Moment Y (Twist)	0.0074
Moment Z	5.3133

### 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	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 2. D + L	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 3. D + (S or Lr or R)	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 3. D + (S or Lr or R)	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 5b. D + 0.7E	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0037	2.4020	-0.0158	-0.0590	0.0040	-0.0173
ULS: 8. 0.6D + 0.7E	0.0022	1.4412	-0.0095	-0.0354	0.0024	-0.0104
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.1572	4.2271	-0.0301	-0.1125	0.0074	2.2804
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.1572	4.2271	-0.0301	-0.1125	0.0074	2.2804
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0458	1.9097	-0.0119	-0.0444	0.0023	1.3356
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1084	1.2429	-0.0069	-0.0258	0.0033	-5.3133

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	-0.1170	3.7708	-0.0266	-0.0992	0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1170	3.7708	-0.0266	-0.0992	0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0353	2.0328	-0.0129	-0.0480	0.0028	0.9974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0823	1.5327	-0.0091	-0.0341	0.0035	-3.9893
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1170	3.7708	-0.0266	-0.0992	0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1170	3.7708	-0.0266	-0.0992	0.0066	1.7060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0353	2.0328	-0.0129	-0.0480	0.0028	0.9974
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0823	1.5327	-0.0091	-0.0341	0.0035	-3.9893
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.1587	3.2663	-0.0238	-0.0889	0.0058	2.2874
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.1587	3.2663	-0.0238	-0.0889	0.0058	2.2874
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0443	0.9489	-0.0055	-0.0208	0.0007	1.3425
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1069	0.2821	-0.0006	-0.0022	0.0017	-5.3064

### 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	5.9241
Shear X	-0.2682
Shear Z	-0.0429
Moment X	-0.1607
Moment Y (Twist)	0.0104
Moment Z	9.1457

### 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	4.2271
Shear X	-0.1587
Shear Z	-0.0301
Moment X	-0.1125
Moment Y (Twist)	0.0074
Moment Z	5.3133

### 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	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 2. D + L	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 3. D + (S or Lr or R)	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 3. D + (S or Lr or R)	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 5b. D + 0.7E	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0037	2.5015	0.0664	0.2462	-0.0156	0.0610
ULS: 8. 0.6D + 0.7E	-0.0022	1.5009	0.0399	0.1477	-0.0094	0.0366
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.1700	4.4167	0.1265	0.4688	-0.0337	2.4304
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.1700	4.4167	0.1265	0.4688	-0.0337	2.4304
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0425	1.9845	0.0506	0.1877	-0.0116	1.4318
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0993	1.2858	0.0277	0.1033	-0.0025	-5.3491
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1285	3.9379	0.1115	0.4131	-0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1285	3.9379	0.1115	0.4131	-0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0310	2.1138	0.0546	0.2023	-0.0126	1.0891
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0736	1.5897	0.0374	0.1390	-0.0058	-3.9966
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1285	3.9379	0.1115	0.4131	-0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1285	3.9379	0.1115	0.4131	-0.0292	1.8380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0310	2.1138	0.0546	0.2023	-0.0126	1.0891
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0736	1.5897	0.0374	0.1390	-0.0058	-3.9966

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.1686	3.4161	0.0999	0.3703	-0.0275	2.4060
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.1686	3.4161	0.0999	0.3703	-0.0275	2.4060
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0440	0.9839	0.0240	0.0892	-0.0054	1.4074
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1008	0.2852	0.0011	0.0048	0.0037	-5.3735

### 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	6.1939
Shear X	-0.2815
Shear Z	0.1802
Moment X	0.6696
Moment Y (Twist)	0.0491
Moment Z	9.2529

### 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	4.4167
Shear X	-0.1700
Shear Z	0.1265
Moment X	0.4688
Moment Y (Twist)	0.0337
Moment Z	5.3735

# Project Details

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

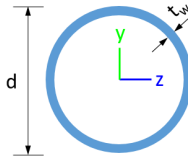


# Design Input Information

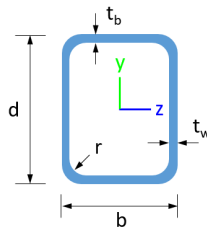
Design Factors			
$\Phi_t$	$\Phi_c$	$\Phi_b$	$\Phi_v$
0.9	0.9	0.9	0.9

Design Materials			
ID	E (ksi)	F <sub>y</sub> (ksi)	F <sub>u</sub> (ksi)
1	29000	50	65

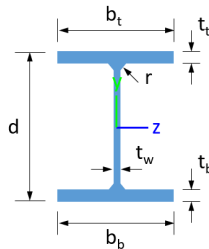
## Section Dimensions



ID	Name	d (in)	t <sub>w</sub> (in)				
1	2in Pipe Sch 40	2.38	0.15				
4	4in Pipe Sch 40	4.50	0.24				
7	6in Pipe Sch 40	6.63	0.28				



ID	Name	d (in)	b (in)	t <sub>w</sub> (in)	t <sub>b</sub> (in)	r (in)	
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12	



ID	Name	d (in)	t <sub>w</sub> (in)	b <sub>t</sub> (in)	b <sub>b</sub> (in)	t <sub>t</sub> (in)	t <sub>b</sub> (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

## Section Properties

ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	I <sub>yp</sub> (in <sup>4</sup> )	I <sub>zp</sub> (in <sup>4</sup> )	I <sub>w</sub> (in <sup>6</sup> )	S <sub>yp</sub> (in <sup>3</sup> )	S <sub>zp</sub> (in <sup>3</sup> )
----	------	----------------------	----------------------	------------------------------------	------------------------------------	-----------------------------------	------------------------------------	------------------------------------







212	142.60	141.72	10.17	10.17	42.60	42.60
213	120.60	84.03	18.39	6.45	30.09	45.74
214	120.60	84.03	18.32	6.45	30.09	45.74
215	120.60	68.63	15.39	6.45	30.09	45.74
216	120.60	68.63	15.04	6.45	30.09	45.74
301	251.16	71.66	42.30	42.30	75.35	75.35
302	142.83	141.72	16.17	16.17	42.85	42.85
303	79.65	74.89	10.99	6.26	29.14	16.61
304	79.65	72.84	10.99	6.26	29.14	16.61
305	79.65	74.30	10.99	6.26	29.14	16.61
306	79.65	74.89	10.99	6.26	29.14	16.61
307	79.65	74.30	10.99	6.26	29.14	16.61
308	120.60	21.74	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.84	10.99	6.26	29.14	16.61
311	120.60	21.74	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	84.03	19.37	6.45	30.09	45.74
314	120.60	84.03	19.28	6.45	30.09	45.74
315	120.60	68.63	17.15	6.45	30.09	45.74
316	120.60	68.63	17.22	6.45	30.09	45.74

## 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	0.086	0.219	0.034	0.004	0.002	0.227	#16	0.663	Not Required	Pass
2	0.000	0.384	0.022	0.076	0.004	0.406	#13	0.052	Not Required	Pass
3	0.001	0.554	0.018	0.057	0.003	0.572	#13	0.044	Not Required	Pass
4	0.001	0.526	0.017	0.053	0.003	0.532	#13	0.078	Not Required	Pass
5	0.001	0.342	0.027	0.056	0.006	0.353	#13	0.073	Not Required	Pass
6	0.001	0.464	0.009	0.046	0.003	0.473	#13	0.044	Not Required	Pass
7	0.001	0.288	0.012	0.047	0.002	0.291	#13	0.073	Not Required	Pass
8	0.001	0.062	0.009	0.031	0.001	0.072	#13	0.088	Not Required	Pass
9	0.001	0.082	0.016	0.002	0.001	0.098	#13	0.198	Not Required	Pass
10	0.001	0.439	0.028	0.045	0.005	0.466	#13	0.078	Not Required	Pass
11	0.001	0.065	0.008	0.032	0.001	0.072	#13	0.059	Not Required	Pass
12	0.001	0.293	0.019	0.063	0.003	0.313	#13	0.034	Not Required	Pass
13	0.001	0.226	0.030	0.041	0.001	0.252	#13	0.177	Not Required	Pass
14	0.001	0.220	0.030	0.039	0.001	0.242	#13	0.177	Not Required	Pass
15	0.000	0.113	0.018	0.029	0.001	0.128	#13	Not Required	Not Required	Pass
16	0.000	0.107	0.018	0.028	0.001	0.122	#13	Not Required	Not Required	Pass
101	0.083	0.216	0.008	0.004	0.001	0.223	#16	0.663	Not Required	Pass
102	0.000	0.303	0.018	0.064	0.003	0.322	#13	0.034	Not Required	Pass
103	0.001	0.476	0.006	0.048	0.001	0.478	#13	0.044	Not Required	Pass
104	0.001	0.448	0.015	0.046	0.003	0.460	#13	0.078	Not Required	Pass
105	0.001	0.294	0.014	0.048	0.003	0.295	#13	0.073	Not Required	Pass
106	0.001	0.497	0.009	0.051	0.002	0.507	#13	0.044	Not Required	Pass
107	0.001	0.307	0.016	0.050	0.003	0.312	#13	0.073	Not Required	Pass
108	0.001	0.045	0.007	0.028	0.001	0.048	#13	0.088	Not Required	Pass
109	0.001	0.056	0.008	0.001	0.000	0.064	#13	0.198	Not Required	Pass
110	0.001	0.470	0.013	0.048	0.002	0.475	#13	0.078	Not Required	Pass

111	0.001	0.046	0.008	0.030	0.001	0.048	#13	0.059	Not Required	Pass
112	0.000	0.325	0.019	0.068	0.003	0.344	#13	0.052	Not Required	Pass
113	0.001	0.132	0.020	0.038	0.001	0.140	#13	0.177	Not Required	Pass
114	0.001	0.127	0.019	0.036	0.001	0.134	#13	0.265	Not Required	Pass
115	0.001	0.108	0.012	0.027	0.001	0.118	#13	0.293	Not Required	Pass
116	0.001	0.103	0.011	0.026	0.001	0.113	#13	0.439	Not Required	Pass
201	0.083	0.216	0.008	0.004	0.001	0.223	#16	0.663	Not Required	Pass
202	0.000	0.325	0.019	0.068	0.003	0.344	#13	0.052	Not Required	Pass
203	0.001	0.497	0.009	0.051	0.002	0.507	#13	0.044	Not Required	Pass
204	0.001	0.470	0.013	0.048	0.002	0.475	#13	0.078	Not Required	Pass
205	0.001	0.307	0.016	0.050	0.003	0.312	#13	0.073	Not Required	Pass
206	0.001	0.476	0.006	0.048	0.001	0.478	#13	0.044	Not Required	Pass
207	0.001	0.294	0.014	0.048	0.003	0.295	#13	0.073	Not Required	Pass
208	0.001	0.033	0.008	0.026	0.001	0.038	#13	0.088	Not Required	Pass
209	0.001	0.056	0.008	0.001	0.000	0.064	#13	0.198	Not Required	Pass
210	0.001	0.448	0.015	0.046	0.003	0.460	#13	0.078	Not Required	Pass
211	0.001	0.034	0.008	0.027	0.001	0.038	#13	0.059	Not Required	Pass
212	0.000	0.303	0.018	0.064	0.003	0.322	#13	0.034	Not Required	Pass
213	0.001	0.132	0.020	0.038	0.001	0.140	#13	0.177	Not Required	Pass
214	0.001	0.127	0.019	0.036	0.001	0.134	#13	0.265	Not Required	Pass
215	0.001	0.146	0.011	0.030	0.001	0.155	#13	0.293	Not Required	Pass
216	0.001	0.141	0.011	0.028	0.001	0.151	#13	0.439	Not Required	Pass
301	0.086	0.219	0.034	0.004	0.002	0.227	#16	0.663	Not Required	Pass
302	0.001	0.293	0.019	0.063	0.003	0.313	#13	0.034	Not Required	Pass
303	0.001	0.464	0.009	0.046	0.003	0.473	#13	0.044	Not Required	Pass
304	0.001	0.439	0.028	0.045	0.005	0.466	#13	0.078	Not Required	Pass
305	0.001	0.288	0.012	0.047	0.002	0.290	#13	0.073	Not Required	Pass
306	0.001	0.554	0.018	0.057	0.003	0.572	#13	0.044	Not Required	Pass
307	0.001	0.342	0.027	0.056	0.006	0.353	#13	0.073	Not Required	Pass
308	0.000	0.107	0.018	0.028	0.001	0.122	#13	Not Required	Not Required	Pass
309	0.001	0.082	0.016	0.002	0.001	0.098	#13	0.198	Not Required	Pass
310	0.001	0.526	0.017	0.053	0.003	0.532	#13	0.078	Not Required	Pass
311	0.000	0.113	0.018	0.029	0.001	0.128	#13	Not Required	Not Required	Pass
312	0.000	0.384	0.022	0.076	0.004	0.406	#13	0.052	Not Required	Pass
313	0.001	0.226	0.030	0.041	0.001	0.252	#13	0.177	Not Required	Pass
314	0.001	0.220	0.030	0.039	0.001	0.242	#13	0.265	Not Required	Pass
315	0.001	0.099	0.012	0.032	0.001	0.110	#13	0.293	Not Required	Pass
316	0.001	0.094	0.011	0.031	0.001	0.104	#13	0.439	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
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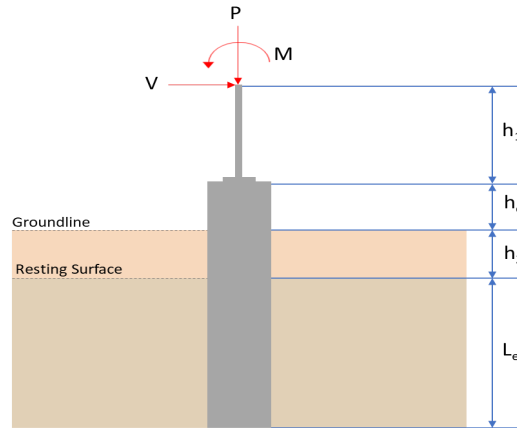
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 4$  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)	4.227	5.924
$V_x$ (kip)	-0.159	-0.268
$V_z$ (kip)	0.030	0.043
$M_x$ (kipft)	0.113	0.161
$M_z$ (kipft)	5.313	9.146

### Material Properties

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

### Required depth to resist lateral loads (ASD)

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.159 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.025318 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(5.313 \text{ kipft}) + ((-0.159 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.84602 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 3.9511 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.03 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0047771 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.113 \text{ kipft}) + ((0.03 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.017994 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.2136 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(3.9511 \text{ ft}), (1.2136 \text{ ft})]$$

$$L_{e,req} = 3.951 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(3.951 \text{ ft})}{(4 \text{ ft})}$$

$$\text{Ratio} = 0.98775$$

Status: **PASS**  
Ratio: **0.990**

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(4.227 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.26419 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.26419 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.13209$$

Status: **PASS**  
Ratio: **0.130**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(4 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.025318 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.84602 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.84602 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.84602 \text{ kipft/ft})) + (4 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.6913 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.84602 \text{ kipft/ft})) + (3 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]^2}{(4 \text{ ft})^2 \times [(3 \times (0.84602 \text{ kipft/ft})) + (2 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.19043 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.84602 \text{ kipft/ft})) + ((-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.59654 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.6913 \text{ ft})}{2}$$

$$p_a = 0.20185 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19043 \text{ kip/ft}^2)}{(0.20185 \text{ kip/ft}^2)}$$

$$Ratio = 0.94343$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4 \text{ ft})$$

$$p_s = 0.6 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.59654 \text{ kip/ft}^2)}{(0.6 \text{ kip/ft}^2)}$$

$$Ratio = 0.99423$$

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

Status: **PASS**  
Ratio: **0.990**

#### Considering z-direction:

$H_o = 0.0047771 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.017994 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.017994 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (0.0047771 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.017994 \text{ kipft/ft})) + (4 \times (0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.8048 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.017994 \text{ kipft/ft})) + (3 \times (0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]^2}{(4 \text{ ft})^2 \times [(3 \times (0.017994 \text{ kipft/ft})) + (2 \times (0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.0085 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.017994 \text{ kipft/ft})) + ((0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.020661 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.8048 \text{ ft})}{2}$$

$$p_a = 0.21036 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0085 \text{ kip/ft}^2)}{(0.21036 \text{ kip/ft}^2)}$$

$$Ratio = 0.040406$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4 \text{ ft})$$

$$p_s = 0.6 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

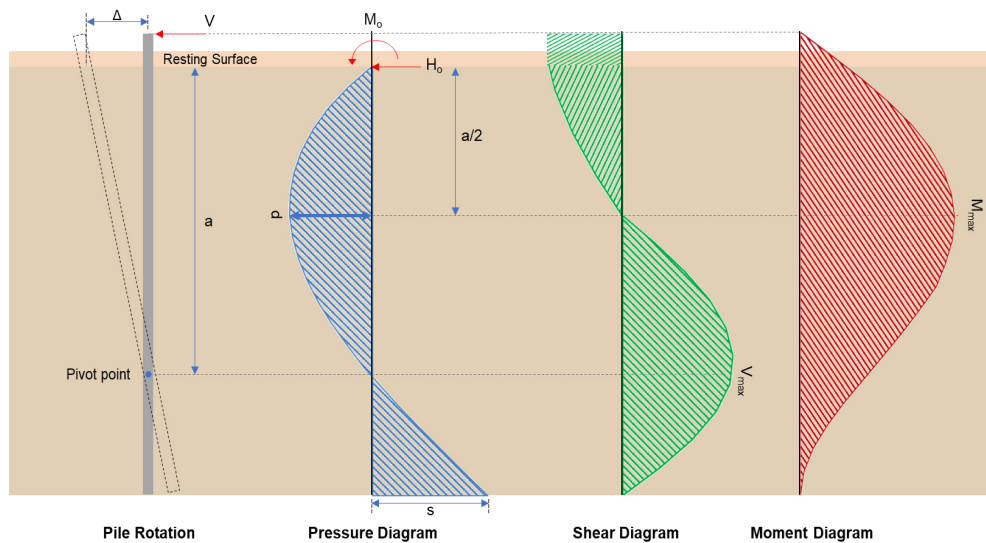
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.020661 \text{ kip/ft}^2)}{(0.6 \text{ kip/ft}^2)}$$

$$Ratio = 0.034435$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.268 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.042675 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(9.146 \text{ kipft}) + ((-0.268 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.4564 \text{ kipft/ft}$$

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

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

$$E = \frac{(1.4564 \text{ kipft/ft})}{(-0.042675 \text{ kip/ft})}$$

$$E = 34.127 \text{ ft}$$

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

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

$$a = \frac{(4 \times (1.4564 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft})^2)}{6 \times (1.4564 \text{ kipft/ft}) + 4 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft})}$$

$$a = \frac{(-0.042675 \text{ kip/ft}) \times (4 \text{ ft})}{(6 \times (1.4564 \text{ kipft/ft})) + (-0.042675 \text{ kip/ft}) \times (4 \text{ ft})}$$

$$a = 2.6908 \text{ ft}$$

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

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

$$V_{max} = ((-0.042675 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.6908 \text{ ft})}{(4 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.6908 \text{ ft})}{(4 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 2.6973 \text{ kip}$$

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

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

$$M_{max} = ((-0.042675 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[ \left( \frac{(34.127 \text{ ft})}{(4 \text{ ft})} + \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right) - \left[ \left( \frac{4 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 5.3317 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.043 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0068471 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.161 \text{ kipft}) + ((0.043 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.025637 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.025637 \text{ kipft/ft})}{(0.0068471 \text{ kip/ft})}$$

$$E = 3.7442 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.025637 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (0.0068471 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.025637 \text{ kipft/ft})) + (4 \times (0.0068471 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.8053 \text{ ft}$$

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

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

$$V_{max} = ((0.0068471 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.8053 \text{ ft})}{(4 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.8053 \text{ ft})}{(4 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.063465 \text{ kip}$$

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

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

$$M_{max} = ((0.0068471 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[ \left( \frac{(3.7442 \text{ ft})}{(4 \text{ ft})} + \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11707 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

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

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

$\alpha = 0.8$  - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(5.924 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.399 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.399 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3 <math>s_{rebar}</math> - Minimum spacing of reinforcement,</p> <p>25.7.2.2 Since longitudinal reinforcement is <math>\leq</math> No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 <math>s_{ties}</math> - Maximum spacing of ties,</p>	<p style="text-align: center;"><math>Ratio = 0.96556</math></p> <p style="text-align: center;"><math>s_{rebar} = Max[1.5, (1.5 d_{bar})]</math></p> <p style="text-align: center;"><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 style="text-align: center;"><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p style="text-align: center;"><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \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>14 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>0.970</b></p>
<p>22.4.2.2 <math>\phi P_N</math> - Allowable axial compressive strength</p>	<p><b>Axial Compression Strength (ACI 318-19, LRFD)</b></p> <p style="text-align: center;"><math>\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \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{(5.924 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0022144</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.000</b></p>
<p>22.5.2.2 <math>b_w</math> = 48 in - Effective width, <math>d</math> - Effective depth</p> <p>22.5.5.1.3 <math>\lambda_s</math> - size effect modification factor</p> <p>22.5.5.1.1 <math>V_{c,max}</math> - Max shear strength of concrete</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p style="text-align: center;"><math>d = 0.80 D</math></p> <p style="text-align: center;"><math>d = 0.80 \times (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \text{ in}</math></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{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</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 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 (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 5.924 \text{ kip} \rightarrow 5924 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(5924 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.28 \text{ kip}$$

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

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.28 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.28 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.28 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.61 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 2.6973 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(2.6973 \text{ kip})}{(110.61 \text{ kip})}$$

$$Ratio = 0.024385$$

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

**Considering z-direction:**

$V_{max} = 0.063465 \text{ kip}$  - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.063465 \text{ kip})}{(110.61 \text{ kip})}$$

$$Ratio = 0.00057378$$

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

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

$S_m$  - Section modulus

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

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

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

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 5.3317 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(5.3317 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.021361$$

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

**Considering z-direction:**

$M_{max} = 0.11707 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.11707 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00046903$$

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

REFERENCES	CALCULATIONS	RESULTS
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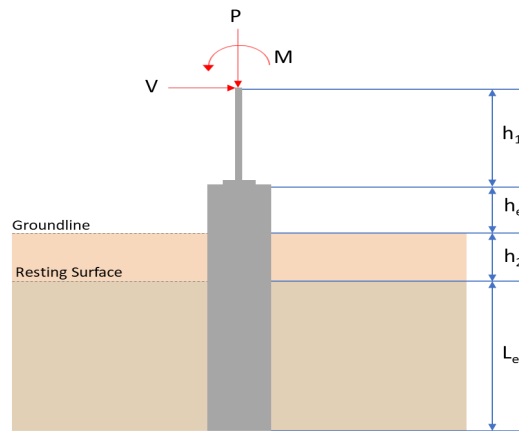
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 4$  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)	4.227	5.924
$V_x$ (kip)	-0.159	-0.268
$V_z$ (kip)	-0.030	-0.043
$M_x$ (kipft)	-0.113	-0.161
$M_z$ (kipft)	5.313	9.146

### Material Properties

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

### Required depth to resist lateral loads (ASD)

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.159 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.025318 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(5.313 \text{ kipft}) + ((-0.159 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.84602 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 3.9511 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.03 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0047771 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.113 \text{ kipft}) + ((-0.03 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.017994 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.0445 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(3.9511 \text{ ft}), (1.0445 \text{ ft})]$$

$$L_{e,req} = 3.951 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(3.951 \text{ ft})}{(4 \text{ ft})}$$

$$\text{Ratio} = 0.98775$$

Status: **PASS**  
Ratio: **0.990**

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(4.227 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.26419 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.26419 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.13209$$

Status: **PASS**  
Ratio: **0.130**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(4 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.025318 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.84602 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.84602 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.84602 \text{ kipft/ft})) + (4 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.6913 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.84602 \text{ kipft/ft})) + (3 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]^2}{(4 \text{ ft})^2 \times [(3 \times (0.84602 \text{ kipft/ft})) + (2 \times (-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.19043 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.84602 \text{ kipft/ft})) + ((-0.025318 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.59654 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.6913 \text{ ft})}{2}$$

$$p_a = 0.20185 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19043 \text{ kip/ft}^2)}{(0.20185 \text{ kip/ft}^2)}$$

$$Ratio = 0.94343$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4 \text{ ft})$$

$$p_s = 0.6 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.59654 \text{ kip/ft}^2)}{(0.6 \text{ kip/ft}^2)}$$

$$Ratio = 0.99423$$

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

Status: **PASS**  
Ratio: **0.990**

#### Considering z-direction:

$H_o = -0.0047771 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.017994 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.017994 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.0047771 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.017994 \text{ kipft/ft})) + (4 \times (-0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.8048 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.017994 \text{ kipft/ft})) + (3 \times (-0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]^2}{(4 \text{ ft})^2 \times [(3 \times (0.017994 \text{ kipft/ft})) + (2 \times (-0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.00063815 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.017994 \text{ kipft/ft})) + ((-0.0047771 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.0063296 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.8048 \text{ ft})}{2}$$

$$p_a = 0.21036 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.00063815 \text{ kip/ft}^2)}{(0.21036 \text{ kip/ft}^2)}$$

$$Ratio = 0.0030336$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4 \text{ ft})$$

$$p_s = 0.6 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

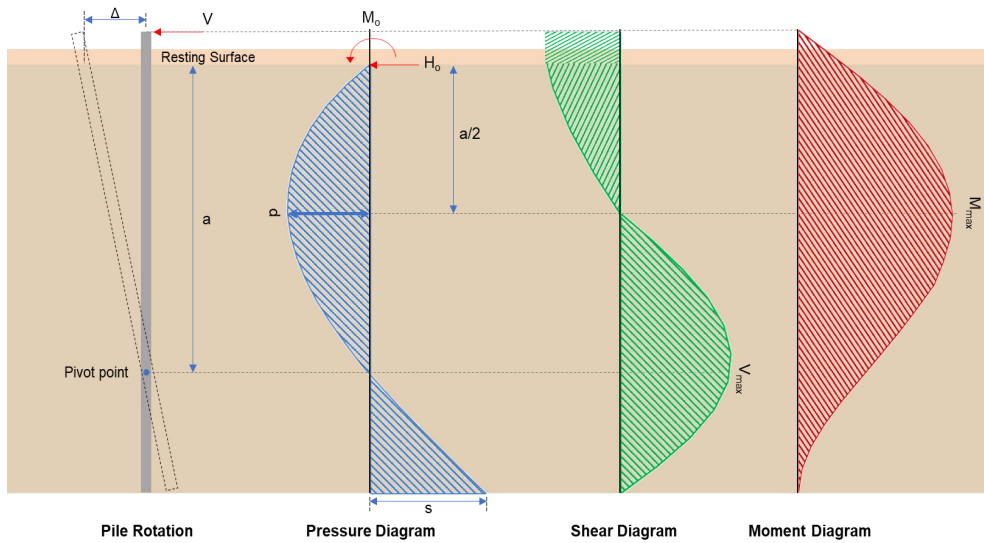
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0063296 \text{ kip/ft}^2)}{(0.6 \text{ kip/ft}^2)}$$

$$Ratio = 0.010549$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.268 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.042675 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(9.146 \text{ kipft}) + ((-0.268 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.4564 \text{ kipft/ft}$$

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

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

$$E = \frac{(1.4564 \text{ kipft/ft})}{(-0.042675 \text{ kip/ft})}$$

$$E = 34.127 \text{ ft}$$

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

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

$$a = \frac{(4 \times (1.4564 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft})^2)}{6 \times (1.4564 \text{ kipft/ft}) + 4 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft})}$$

$$a = \frac{(6 \times (1.4564 \text{ kipft/ft})) + (4 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft}))}{(6 \times (1.4564 \text{ kipft/ft})) + (4 \times (-0.042675 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.6908 \text{ ft}$$

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

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

$$V_{max} = ((-0.042675 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.6908 \text{ ft})}{(4 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.6908 \text{ ft})}{(4 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 2.6973 \text{ kip}$$

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

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

$$M_{max} = ((-0.042675 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[ \left( \frac{(34.127 \text{ ft})}{(4 \text{ ft})} + \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right) - \left[ \left( \frac{4 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (34.127 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.6908 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 5.3317 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.043 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0068471 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.161 \text{ kipft}) + ((-0.043 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.025637 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.025637 \text{ kipft/ft})}{(-0.0068471 \text{ kip/ft})}$$

$$E = 3.7442 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.025637 \text{ kipft/ft}) \times (4 \text{ ft})) + (3 \times (-0.0068471 \text{ kip/ft}) \times (4 \text{ ft})^2)}{(6 \times (0.025637 \text{ kipft/ft})) + (4 \times (-0.0068471 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.8053 \text{ ft}$$

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

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

$$V_{max} = ((-0.0068471 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.8053 \text{ ft})}{(4 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.8053 \text{ ft})}{(4 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.063465 \text{ kip}$$

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

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

$$M_{max} = ((-0.0068471 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[ \left( \frac{(3.7442 \text{ ft})}{(4 \text{ ft})} + \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left( \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7442 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left( \frac{(2.8053 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11707 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

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

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

$\alpha = 0.8$  - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(5.924 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.399 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.399 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = 0.96556</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><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>14 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>0.970</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 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(5.924 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0022144</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.000</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 = 48 \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 (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \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{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</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 (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 5.924 \text{ kip} \rightarrow 5924 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(5924 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.28 \text{ kip}$$

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

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.28 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.28 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.28 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.61 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 2.6973 \text{ kip}$  - Maximum shear force in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(2.6973 \text{ kip})}{(110.61 \text{ kip})}$$

$$Ratio = 0.024385$$

**Considering z-direction:**

$V_{max} = 0.063465 \text{ kip}$  - Maximum shear force in the z-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(0.063465 \text{ kip})}{(110.61 \text{ kip})}$$

$$Ratio = 0.00057378$$

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

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

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

$S_m$  - Section modulus

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

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

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

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 5.3317 \text{ kipft}$  - Maximum moment in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(5.3317 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.021361$$

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

**Considering z-direction:**

$M_{max} = 0.11707 \text{ kipft}$  - Maximum moment in the z-direction,

$Ratio$  - Capacity

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

$$\text{Ratio} = \frac{(0.11707 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00046903$$

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

REFERENCES	CALCULATIONS	RESULTS
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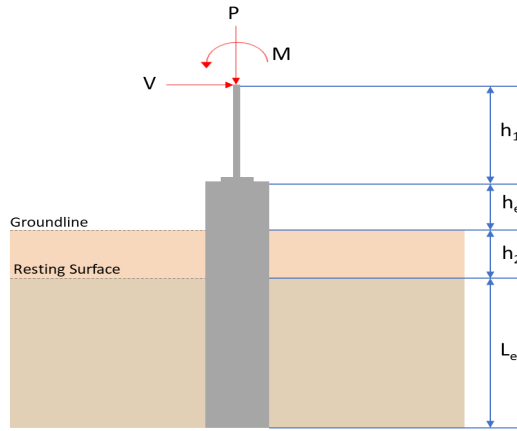
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 4.25$  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)	4.417	6.194
$V_x$ (kip)	-0.170	-0.282
$V_z$ (kip)	-0.127	-0.180
$M_x$ (kipft)	-0.469	-0.670
$M_z$ (kipft)	5.373	9.253

### Material Properties

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

### Required depth to resist lateral loads (ASD)

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.17 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.02707 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(5.373 \text{ kipft}) + ((-0.17 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.85557 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 3.9582 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.127 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.020223 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.469 \text{ kipft}) + ((-0.127 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.074682 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.5929 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(3.9582 \text{ ft}), (1.5929 \text{ ft})]$$

$$L_{e,req} = 3.958 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(3.958 \text{ ft})}{(4.25 \text{ ft})}$$

$$\text{Ratio} = 0.93129$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(4.417 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.27606 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.27606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.13803$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(4.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.0625$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.02707 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.85557 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.85557 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.85557 \text{ kipft/ft})) + (4 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.8625 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.85557 \text{ kipft/ft})) + (3 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]^2}{(4.25 \text{ ft})^2 \times [(3 \times (0.85557 \text{ kipft/ft})) + (2 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]}$$

$$p = 0.16826 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.85557 \text{ kipft/ft})) + ((-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]}{(4.25 \text{ ft})^2}$$

$$s = 0.53019 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.8625 \text{ ft})}{2}$$

$$p_a = 0.21469 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.16826 \text{ kip/ft}^2)}{(0.21469 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.78377$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.25 \text{ ft})$$

$$p_s = 0.6375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.53019 \text{ kip/ft}^2)}{(0.6375 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.83167$$

Status: **PASS**  
Ratio: **0.780**

Status: **PASS**  
Ratio: **0.830**

#### Considering z-direction:

$H_o = -0.020223 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.074682 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.074682 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.020223 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.074682 \text{ kipft/ft})) + (4 \times (-0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.9871 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.074682 \text{ kipft/ft})) + (3 \times (-0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]^2}{(4.25 \text{ ft})^2 \times [(3 \times (0.074682 \text{ kipft/ft})) + (2 \times (-0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]}$$

$$p = 0.0013309 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.074682 \text{ kipft/ft})) + ((-0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]}{(4.25 \text{ ft})^2}$$

$$s = 0.021065 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.9871 \text{ ft})}{2}$$

$$p_a = 0.22403 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0013309 \text{ kip/ft}^2)}{(0.22403 \text{ kip/ft}^2)}$$

$$Ratio = 0.0059405$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.25 \text{ ft})$$

$$p_s = 0.6375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

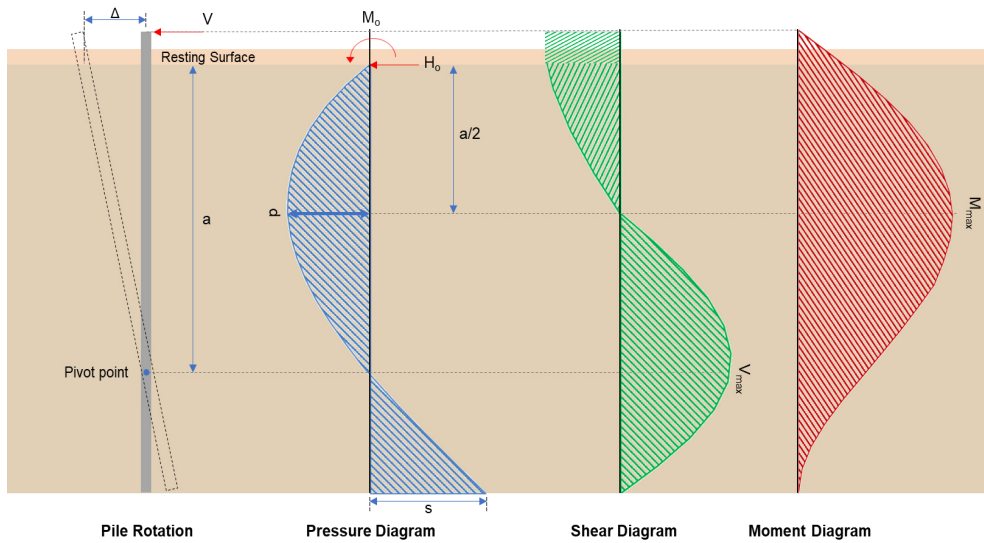
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.021065 \text{ kip/ft}^2)}{(0.6375 \text{ kip/ft}^2)}$$

$$Ratio = 0.033044$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.282 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.044904 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(9.253 \text{ kipft}) + ((-0.282 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.4734 \text{ kipft/ft}$$

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

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

$$E = \frac{(1.4734 \text{ kipft/ft})}{(-0.044904 \text{ kip/ft})}$$

$$E = 32.812 \text{ ft}$$

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

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

$$a = \frac{(4 \times (1.4734 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (1.4734 \text{ kipft/ft})) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = \frac{(6 \times (1.4734 \text{ kipft/ft})) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}{(6 \times (1.4734 \text{ kipft/ft})) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.8615 \text{ ft}$$

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

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

$$V_{max} = ((-0.044904 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.8615 \text{ ft})}{(4.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.8615 \text{ ft})}{(4.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 2.5792 \text{ kip}$$

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

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

$$M_{max} = ((-0.044904 \text{ kip/ft}) \times (48 \text{ in}) \times (4.25 \text{ ft})) \times \left[ \left( \frac{(32.812 \text{ ft})}{(4.25 \text{ ft})} + \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 5.4105 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.18 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.028662 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.67 \text{ kipft}) + ((-0.18 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.10669 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.10669 \text{ kipft/ft})}{(-0.028662 \text{ kip/ft})}$$

$$E = 3.7222 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.10669 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.028662 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.10669 \text{ kipft/ft})) + (4 \times (-0.028662 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.9864 \text{ ft}$$

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

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

$$V_{max} = ((-0.028662 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.9864 \text{ ft})}{(4.25 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.9864 \text{ ft})}{(4.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.2535 \text{ kip}$$

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

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

$$M_{max} = ((-0.028662 \text{ kip/ft}) \times (48 \text{ in}) \times (4.25 \text{ ft})) \times \left[ \left( \frac{(3.7222 \text{ ft})}{(4.25 \text{ ft})} + \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.49487 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

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

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

$\alpha = 0.8$  - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(6.194 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.39 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.39 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = 0.96556</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><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>14 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>0.970</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 0.80 [(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 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(6.194 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0023154</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.000</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 = 48 \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 (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \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{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</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 (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 6.194 \text{ kip} \rightarrow 6194 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(6194 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.31 \text{ kip}$$

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

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.31 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.31 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.31 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.63 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 2.5792 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(2.5792 \text{ kip})}{(110.63 \text{ kip})}$$

$$Ratio = 0.023313$$

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

**Considering z-direction:**

$V_{max} = 0.2535 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.2535 \text{ kip})}{(110.63 \text{ kip})}$$

$$Ratio = 0.0022914$$

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

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

$S_m$  - Section modulus

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

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

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

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 5.4105 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(5.4105 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.021677$$

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

**Considering z-direction:**

$M_{max} = 0.49487 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.49487 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0019827$$

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

REFERENCES	CALCULATIONS	RESULTS
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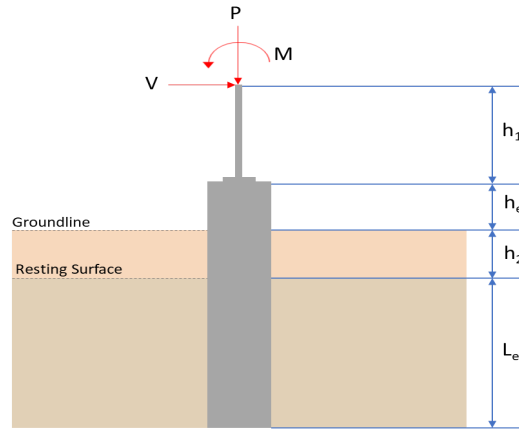
## SkyCiv Foundation Design

Pile Foundation

### Design Information :

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

### Pile Input



### Geometry

Pile shape: rectangular

$b = 48$  in - Pile width

$D = 48$  in - Pile depth

$L = 4.25$  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)	4.417	6.194
$V_x$ (kip)	-0.170	-0.282
$V_z$ (kip)	0.127	0.180
$M_x$ (kipft)	0.469	0.670
$M_z$ (kipft)	5.373	9.253

### Material Properties

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

### Required depth to resist lateral loads (ASD)

$H$  - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

### Considering x-direction:

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.17 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.02707 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(5.373 \text{ kipft}) + ((-0.17 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.85557 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 3.9582 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.127 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.020223 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.469 \text{ kipft}) + ((0.127 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.074682 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.0364 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(3.9582 \text{ ft}), (2.0364 \text{ ft})]$$

$$L_{e,req} = 3.958 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(3.958 \text{ ft})}{(4.25 \text{ ft})}$$

$$\text{Ratio} = 0.93129$$

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

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(4.417 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.27606 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.27606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.13803$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(4.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.0625$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.02707 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.85557 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.85557 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.85557 \text{ kipft/ft})) + (4 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.8625 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.85557 \text{ kipft/ft})) + (3 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]^2}{(4.25 \text{ ft})^2 \times [(3 \times (0.85557 \text{ kipft/ft})) + (2 \times (-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]}$$

$$p = 0.16826 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.85557 \text{ kipft/ft})) + ((-0.02707 \text{ kip/ft}) \times (4.25 \text{ ft}))]}{(4.25 \text{ ft})^2}$$

$$s = 0.53019 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.8625 \text{ ft})}{2}$$

$$p_a = 0.21469 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.16826 \text{ kip/ft}^2)}{(0.21469 \text{ kip/ft}^2)}$$

$$Ratio = 0.78377$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.25 \text{ ft})$$

$$p_s = 0.6375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.53019 \text{ kip/ft}^2)}{(0.6375 \text{ kip/ft}^2)}$$

$$Ratio = 0.83167$$

Status: **PASS**  
Ratio: **0.780**

Status: **PASS**  
Ratio: **0.830**

#### Considering z-direction:

$H_o = 0.020223 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.074682 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.074682 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (0.020223 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.074682 \text{ kipft/ft})) + (4 \times (0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.9871 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.074682 \text{ kipft/ft})) + (3 \times (0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]^2}{(4.25 \text{ ft})^2 \times [(3 \times (0.074682 \text{ kipft/ft})) + (2 \times (0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]}$$

$$p = 0.032486 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.074682 \text{ kipft/ft})) + ((0.020223 \text{ kip/ft}) \times (4.25 \text{ ft}))]}{(4.25 \text{ ft})^2}$$

$$s = 0.078165 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.9871 \text{ ft})}{2}$$

$$p_a = 0.22403 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.032486 \text{ kip/ft}^2)}{(0.22403 \text{ kip/ft}^2)}$$

$$Ratio = 0.145$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (4.25 \text{ ft})$$

$$p_s = 0.6375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

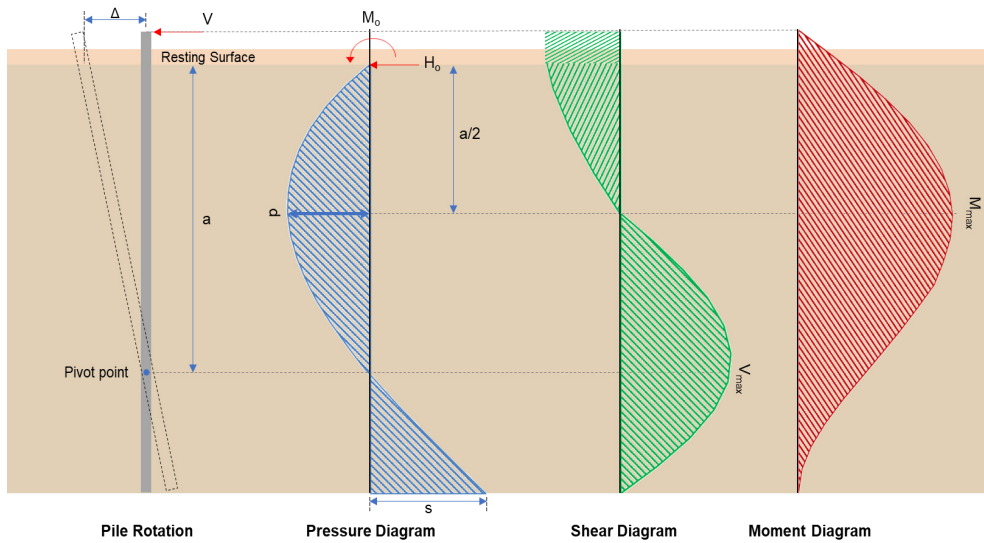
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.078165 \text{ kip/ft}^2)}{(0.6375 \text{ kip/ft}^2)}$$

$$Ratio = 0.12261$$

Status: **PASS**  
Ratio: **0.150**

Status: **PASS**  
Ratio: **0.120**



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.282 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.044904 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(9.253 \text{ kipft}) + ((-0.282 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.4734 \text{ kipft/ft}$$

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

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

$$E = \frac{(1.4734 \text{ kipft/ft})}{(-0.044904 \text{ kip/ft})}$$

$$E = 32.812 \text{ ft}$$

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

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

$$a = \frac{(4 \times (1.4734 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (1.4734 \text{ kipft/ft})) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = \frac{6 \times (1.4734 \text{ kipft/ft}) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}{(6 \times (1.4734 \text{ kipft/ft}) + (4 \times (-0.044904 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.8615 \text{ ft}$$

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

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

$$V_{max} = ((-0.044904 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.8615 \text{ ft})}{(4.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.8615 \text{ ft})}{(4.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 2.5792 \text{ kip}$$

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

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

$$M_{max} = ((-0.044904 \text{ kip/ft}) \times (48 \text{ in}) \times (4.25 \text{ ft})) \times \left[ \left( \frac{(32.812 \text{ ft})}{(4.25 \text{ ft})} + \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (32.812 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.8615 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 5.4105 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.18 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.028662 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.67 \text{ kipft}) + ((0.18 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.10669 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.10669 \text{ kipft/ft})}{(0.028662 \text{ kip/ft})}$$

$$E = 3.7222 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.10669 \text{ kipft/ft}) \times (4.25 \text{ ft})) + (3 \times (0.028662 \text{ kip/ft}) \times (4.25 \text{ ft})^2)}{(6 \times (0.10669 \text{ kipft/ft})) + (4 \times (0.028662 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.9864 \text{ ft}$$

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

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

$$V_{max} = ((0.028662 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.9864 \text{ ft})}{(4.25 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.9864 \text{ ft})}{(4.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.2535 \text{ kip}$$

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

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

$$M_{max} = ((0.028662 \text{ kip/ft}) \times (48 \text{ in}) \times (4.25 \text{ ft})) \times \left[ \left( \frac{(3.7222 \text{ ft})}{(4.25 \text{ ft})} + \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 3 \right) \times \left( \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7222 \text{ ft})}{(4.25 \text{ ft})} + 2 \right) \times \left( \frac{(2.9864 \text{ ft})}{2 \times (4.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.49487 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

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

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

$\alpha = 0.8$  - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$  - Gross area of concrete,

#### Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(6.194 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.39 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.39 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;"><math>Ratio = 0.96556</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><math>s_{rebar} = 1.5 \text{ in}</math></p> <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]</math></p> <p><math>s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]</math></p> <p><math>s_{ties} = 10 \text{ in}</math></p> <p><b>Summary:</b></p> <p style="text-align: center;">Main reinforcement: <b>14 - #5 (0.625 in)</b> Ties: <b>#3(0.375 in) - 10 in</b></p>	<p>Status: <b>PASS</b> Ratio: <b>0.970</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 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]</math></p> <p style="text-align: center;"><math>\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]</math></p> <p style="text-align: center;"><math>\phi P_N = 2675.2 \text{ kip}</math></p> <p>Ratio - Capacity</p> <p style="text-align: center;"><math>Ratio = \frac{P}{\phi P_N}</math></p> <p style="text-align: center;"><math>Ratio = \frac{(6.194 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0023154</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.000</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 = 48 \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 (48 \text{ in})</math></p> <p style="text-align: center;"><math>d = 38.4 \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{(38.4 \text{ in})}{10}}}, 1 \right]</math></p> <p style="text-align: center;"><math>\lambda_s = 0.64282</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 (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})</math></p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 6.194 \text{ kip} \rightarrow 6194 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(6194 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.31 \text{ kip}$$

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

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (119.31 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.31 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.31 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.63 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 2.5792 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(2.5792 \text{ kip})}{(110.63 \text{ kip})}$$

$$Ratio = 0.023313$$

**Considering z-direction:**

$V_{max} = 0.2535 \text{ kip}$  - Maximum shear force in the z-direction,  
*Ratio* - Capacity

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

$$Ratio = \frac{(0.2535 \text{ kip})}{(110.63 \text{ kip})}$$

$$Ratio = 0.0022914$$

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

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

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

$S_m$  - Section modulus

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

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

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

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

Allowable flexural strength:

$M_n$  shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

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

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

**Considering x-direction:**

$M_{max} = 5.4105 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$Ratio = \frac{(5.4105 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.021677$$

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

**Considering z-direction:**

$M_{max} = 0.49487 \text{ kipft}$  - Maximum moment in the z-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(0.49487 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.0019827$$

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