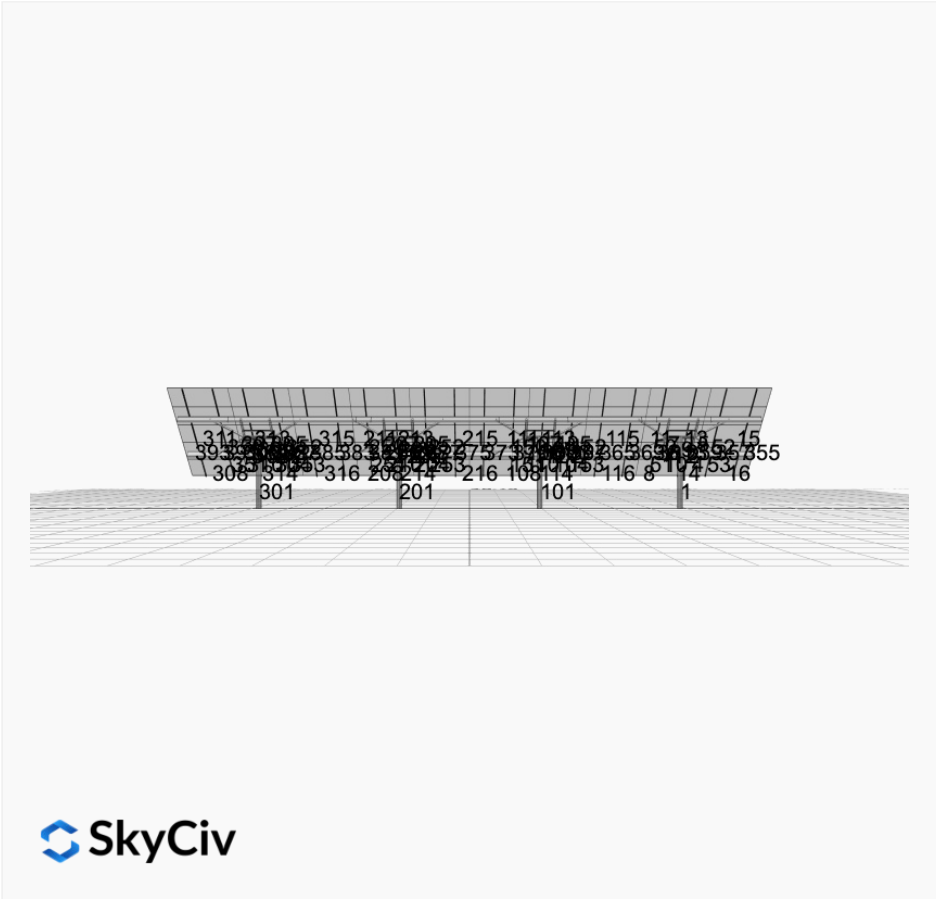


**Project Name:** Keystone State Park 5x10 1975ft - V1Jb  
**Date:** Mon Mar 31 2025  
**Location:** 1150 Keystone Park Rd, Derry, PA 15627, USA  
**Number of Modules:** 50  
**Number of Poles:** 4  
**Unique ID:** 4P-19.75-8TOP-XD-84-L-5Hx10W-STRUTS-IC3L  
**Date Sold:** \_\_\_\_\_  
**Dealer:** \_\_\_\_\_



Array Dimensions N/S	18.79 ft
Array Dimensions E/W	81.58 ft
Winter Tilt Angle	40
Front Edge Clearance	4 ft

**MT Solar Bill of Materials (4P-19.75-8TOP-XD-84-L-5Hx10W-STRUTS-IC3L)**

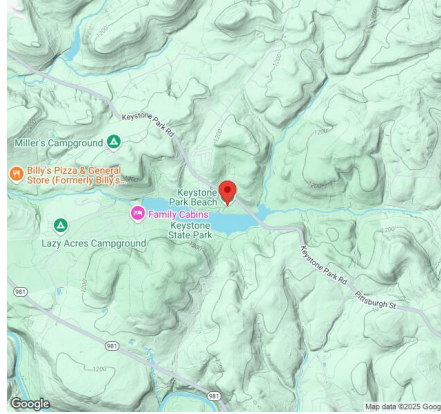
Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-84	84IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	10

**Rail Bill of Materials**

Part	Qty

<b>Part</b>	<b>Qty</b>
Rails (226in)	20
Rail Attachment	80
Module Mid Clamp	80
Module End Clamp	40
Ground Lug	10

## Site Details:



**Site Address:** 1150 Keystone Park Rd, Derry, PA 15627, USA

### Array Specification

<b>Duty Classification:</b>	XD
<b>Module Width:</b>	44.60 in
<b>Module Length:</b>	96.90in
<b>Number of Rows:</b>	5
<b>Number of Columns:</b>	10
<b>Total Number of Modules:</b>	50
<b>Winter Tilt Angle:</b>	40
<b>Front Edge Clearance:</b>	4
<b>Total Array Height at Tilt:</b>	16.08 ft
<b>Total Frame Length:</b>	80.75 ft
<b>Module Info/Notes:</b>	
<b>Array Dimensions N/S:</b>	18.79 ft
<b>Array Dimensions E/W:</b>	81.58 ft
<b>Rail Length:</b>	225.50 in
<b>Rail Spacing:</b>	4.08 ft

### Support Specifications

<b>Pole Size:</b>	8in Pipe Sch 40
<b>Pole Length above Grade:</b>	10.04 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: 7.00 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 7.00 ft
<b>Foundation Volume:</b>	16,296 y <sup>3</sup>

### Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	B
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	1150 Keystone Park Rd, Derry, PA 15627, USA
<b>Wind Speed:</b>	103 mph

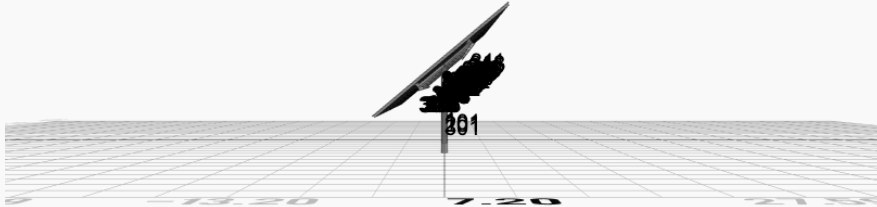
**Snow Load:**

44 psf

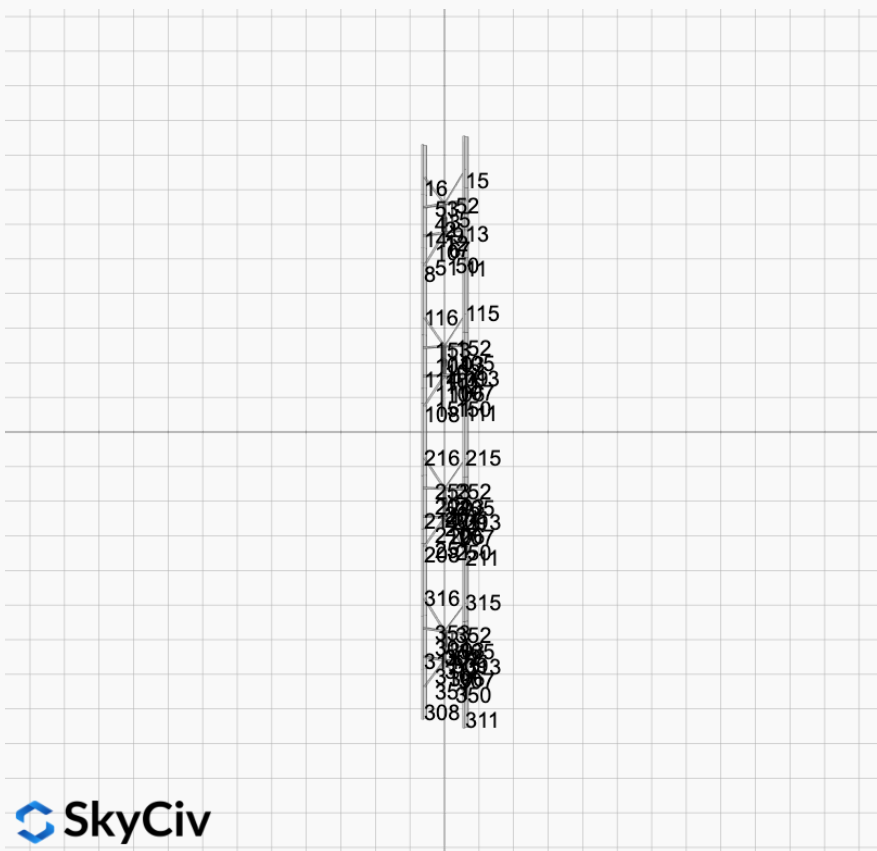
### **Design Disclaimer**


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.





 SkyCiv

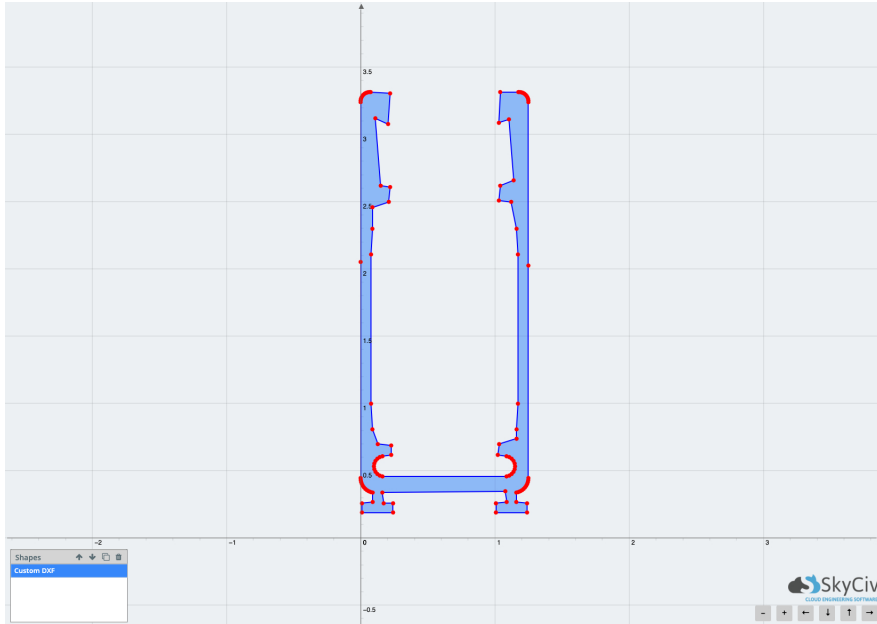


 SkyCiv



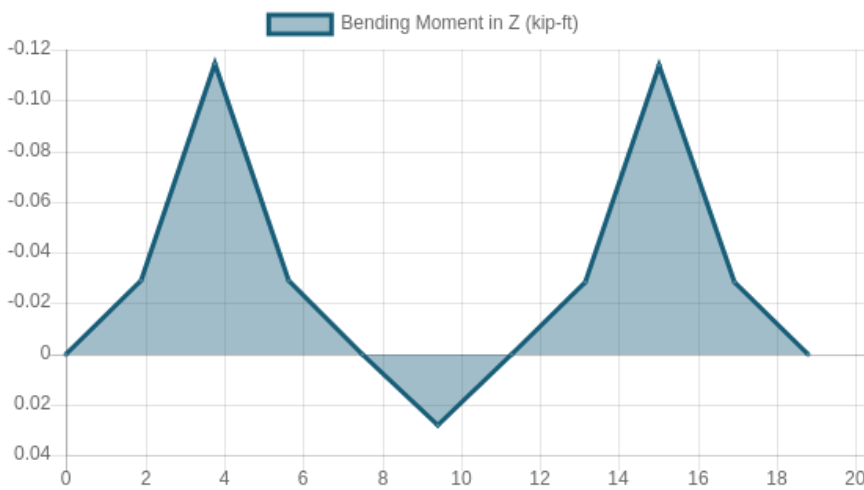
### Rail Design Check

**Rail Length:** 18.79166666666668 ft  
**Additional Restraints Required:** 4ft Spread Clamps  
**Tributary Width:** 4.07916666666667 ft  
**Material:** Aluminium  
**Density:** 169 lb/ft<sup>3</sup>  
**Elasticity Modulus:** 10000 ksi  
**Fy:** 34.5 ksi  
**Fu:** 37 ksi  
**Snow (X):** 0.0454 kip/ft  
**Snow (Y):** -0.0381 kip/ft  
**Wind uplift Case A:** 0.0797 kip/ft  
**Wind uplift Case A:** 0.0797 kip/ft  
**Wind uplift Case B (X):** 0.0000 kip/ft  
**Wind uplift Case B (Y):** 0.1048 kip/ft

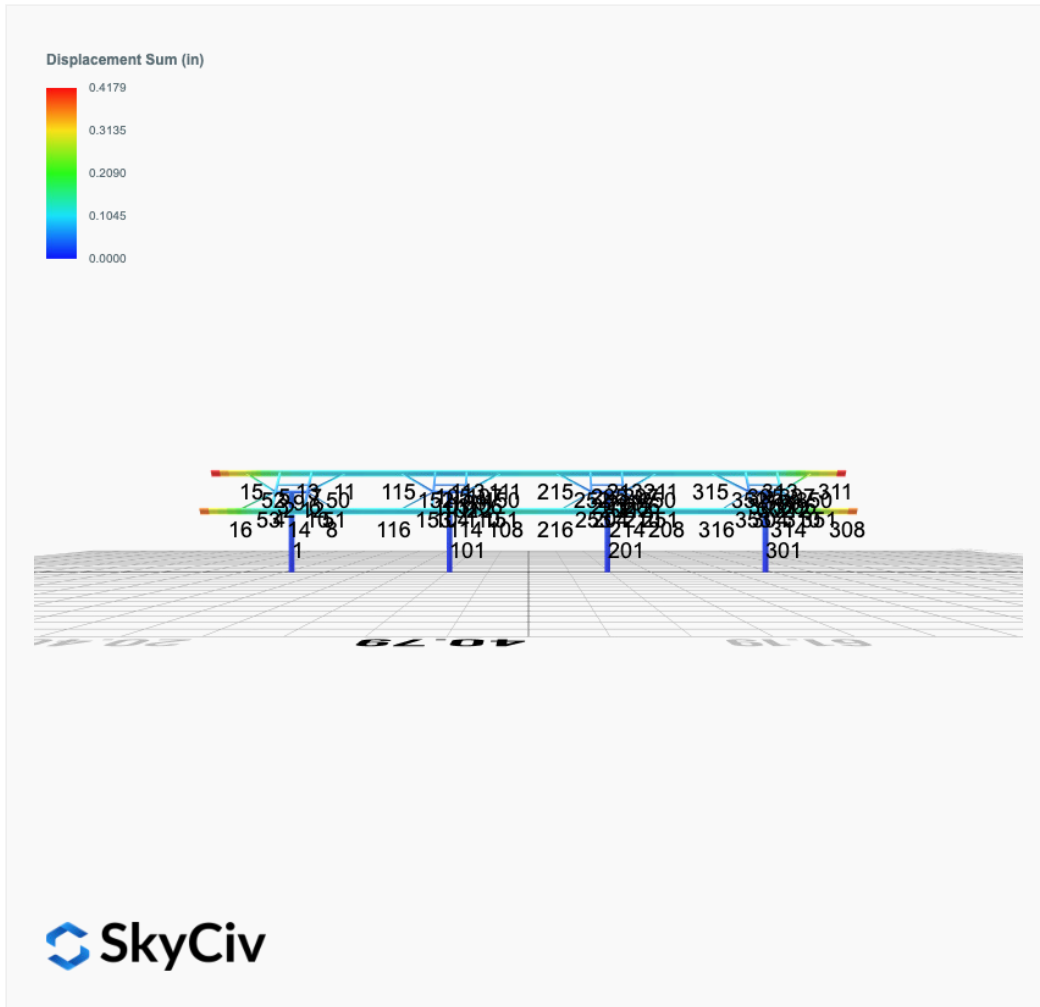


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	20.73295256	0.601	PASS
Material Yield	34.5	20.73295256	0.601	PASS
Material Strength	37	20.73295256	0.560	PASS

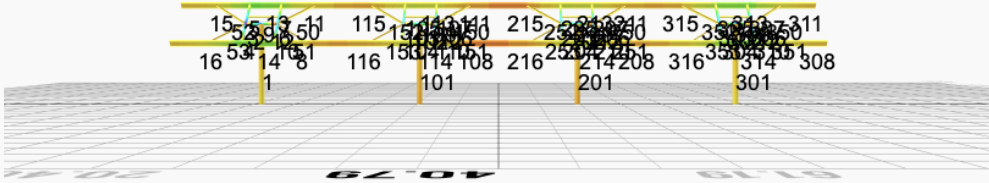
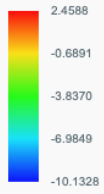
Member 1, ULS: 1.1.14D



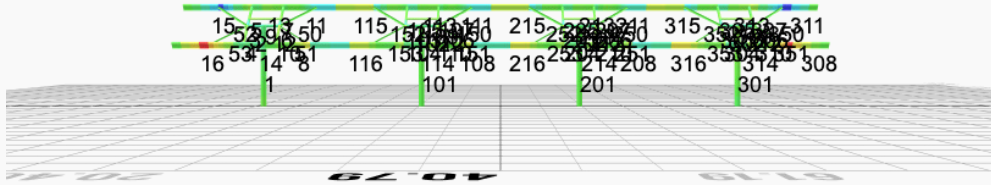
# FEM Results (Envelope Worst Case for each member)



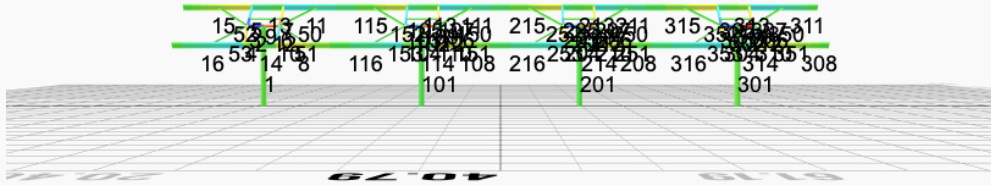
Top Bending Stress Z (ksi)



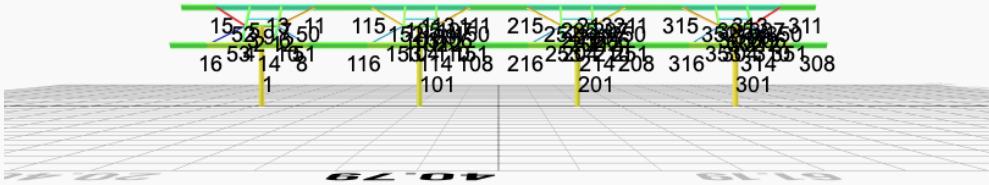
Top Bending Stress Y (ksi)



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	-0.0397	2.9217	-0.0755	-0.2081	0.1979	0.4028
ULS: 2, D + L	-0.0397	2.9217	-0.0755	-0.2081	0.1979	0.4028
ULS: 3, D + (S or Lr or R)	-0.1155	7.3788	-0.2205	-0.6078	0.5775	1.1475
ULS: 3, D + (S or Lr or R)	-0.0397	2.9217	-0.0755	-0.2081	0.1979	0.4028
ULS: 4, D + 0.75L + 0.75(S or Lr or R)	-0.0965	6.2645	-0.1842	-0.5079	0.4826	0.9613
ULS: 4, D + 0.75L + 0.75(S or Lr or R)	-0.0397	2.9217	-0.0755	-0.2081	0.1979	0.4028
ULS: 5b, D + 0.7E	-0.0397	2.9217	-0.0755	-0.2081	0.1979	0.4028
ULS: 6b, D + 0.75L + 0.75(0.7)E + 0.75S	-0.0965	6.2645	-0.1842	-0.5079	0.4826	0.9613
ULS: 8, 0.6D + 0.7E	-0.0238	1.7530	-0.0453	-0.1248	0.1187	0.2417
ULS: 5a, D + 0.6W_Wind downforce Case A only	-3.7797	7.5048	-0.3205	-0.8840	0.9734	39.3361
ULS: 5a, D + 0.6W_Wind downforce Case B only	-3.7797	7.5048	-0.3205	-0.8840	0.9734	39.3361
ULS: 5a, D + 0.6W_Wind uplift Case A only	2.9489	-0.7307	0.1167	0.3206	-0.4101	-28.7678
ULS: 5a, D + 0.6W_Wind uplift Case B only	2.4744	-0.1861	0.0981	0.2694	-0.3608	-32.8918
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9015	9.7018	-0.3680	-1.0149	1.0641	30.1613
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9015	9.7018	-0.3680	-1.0149	1.0641	30.1613
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1450	3.5252	-0.0401	-0.1114	0.0265	-20.9166
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.7891	3.9337	-0.0540	-0.1498	0.0635	-24.0097
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.8447	6.3590	-0.2592	-0.7150	0.7795	29.6028
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.8447	6.3590	-0.2592	-0.7150	0.7795	29.6028
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2018	0.1824	0.0687	0.1885	-0.2581	-21.4751
ULS: 6a, D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8459	0.5909	0.0547	0.1500	-0.2212	-24.5682
ULS: 7, 0.6D + 0.6W_Wind downforce Case A only	-3.7638	6.3361	-0.2903	-0.8008	0.8942	39.1750
ULS: 7, 0.6D + 0.6W_Wind downforce Case B only	-3.7638	6.3361	-0.2903	-0.8008	0.8942	39.1750
ULS: 7, 0.6D + 0.6W_Wind uplift Case A only	2.9648	-1.8994	0.1469	0.4039	-0.4893	-28.9289
ULS: 7, 0.6D + 0.6W_Wind uplift Case B only	2.4903	-1.3548	0.1283	0.3527	-0.4400	-33.0529

### 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	14.4609
Shear X	-6.3153
Shear Z	-0.5770
Moment X	-1.5932
Moment Y (Twist)	1.7365
Moment Z	66.7415

### 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	9.7018
Shear X	-3.7797
Shear Z	-0.3680
Moment X	-1.0149
Moment Y (Twist)	1.0641
Moment Z	39.3361

## 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	0.0397	2.6738	0.0100	0.0257	-0.0301	-0.3446
ULS: 2, D + L	0.0397	2.6738	0.0100	0.0257	-0.0301	-0.3446
ULS: 3, D + (S or Lr or R)	0.1155	6.6531	0.0292	0.0748	-0.0872	-1.0399
ULS: 3, D + (S or Lr or R)	0.0397	2.6738	0.0100	0.0257	-0.0301	-0.3446
ULS: 4, D + 0.75L + 0.75(S or Lr or R)	0.0965	5.6583	0.0244	0.0626	-0.0729	-0.8661

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0397	2.6738	0.0100	0.0257	-0.0301	-0.3446
ULS: 5b. D + 0.7E	0.0397	2.6738	0.0100	0.0257	-0.0301	-0.3446
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0965	5.6583	0.0244	0.0626	-0.0729	-0.8661
ULS: 8. 0.6D + 0.7E	0.0238	1.6043	0.0060	0.0154	-0.0180	-0.2068
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.3312	6.5653	0.0389	0.0990	-0.0852	34.8990
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.3312	6.5653	0.0389	0.0990	-0.0852	34.8990
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7185	-0.4279	-0.0144	-0.0369	0.0208	-26.7319
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.3375	0.0470	-0.0057	-0.0134	-0.0115	-30.7889
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4317	8.5769	0.0461	0.1175	-0.1143	25.5667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4317	8.5769	0.0461	0.1175	-0.1143	25.5667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1056	3.3320	0.0061	0.0156	-0.0348	-20.6566
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8199	3.6882	0.0126	0.0332	-0.0590	-23.6993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4885	5.5924	0.0317	0.0806	-0.0715	26.0881
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4885	5.5924	0.0317	0.0806	-0.0715	26.0881
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0488	0.3475	-0.0083	-0.0213	0.0081	-20.1351
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.7631	0.7037	-0.0018	-0.0036	-0.0161	-23.1778
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.3471	5.4957	0.0349	0.0887	-0.0732	35.0369
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.3471	5.4957	0.0349	0.0887	-0.0732	35.0369
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7026	-1.4975	-0.0184	-0.0472	0.0328	-26.5941
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.3216	-1.0226	-0.0097	-0.0237	0.0005	-30.6510

### 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	12.8140
Shear X	-5.6183
Shear Z	0.0695
Moment X	0.1769
Moment Y (Twist)	0.1700
Moment Z	58.8357

### 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	8.5769
Shear X	-3.3471
Shear Z	0.0461
Moment X	0.1175
Moment Y (Twist)	0.1143
Moment Z	35.0369

### 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	0.0397	2.6738	-0.0100	-0.0257	0.0301	-0.3446
ULS: 2. D + L	0.0397	2.6738	-0.0100	-0.0257	0.0301	-0.3446
ULS: 3. D + (S or Lr or R)	0.1155	6.6531	-0.0292	-0.0748	0.0872	-1.0399
ULS: 3. D + (S or Lr or R)	0.0397	2.6738	-0.0100	-0.0257	0.0301	-0.3446
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0965	5.6583	-0.0244	-0.0625	0.0729	-0.8661
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0397	2.6738	-0.0100	-0.0257	0.0301	-0.3446
ULS: 5b. D + 0.7E	0.0397	2.6738	-0.0100	-0.0257	0.0301	-0.3446
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0965	5.6583	-0.0244	-0.0625	0.0729	-0.8661
ULS: 8. 0.6D + 0.7E	0.0238	1.6043	-0.0060	-0.0154	0.0180	-0.2068
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.3312	6.5653	-0.0389	-0.0990	0.0853	34.8990
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.3312	6.5653	-0.0389	-0.0990	0.0853	34.8990
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7185	-0.4279	0.0144	0.0369	-0.0208	-26.7319
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.3375	0.0470	0.0057	0.0134	0.0115	-30.7889

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4317	8.5769	-0.0461	-0.1175	0.1143	25.5667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4317	8.5769	-0.0461	-0.1175	0.1143	25.5667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1056	3.3320	-0.0061	-0.0156	0.0348	-20.6566
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8199	3.6882	-0.0126	-0.0332	0.0590	-23.6993
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4885	5.5924	-0.0317	-0.0806	0.0715	26.0881
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4885	5.5924	-0.0317	-0.0806	0.0715	26.0881
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0488	0.3475	0.0083	0.0213	-0.0081	-20.1351
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.7631	0.7037	0.0018	0.0036	0.0161	-23.1778
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.3471	5.4957	-0.0349	-0.0887	0.0732	35.0369
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.3471	5.4957	-0.0349	-0.0887	0.0732	35.0369
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7026	-1.4975	0.0184	0.0472	-0.0328	-26.5941
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.3216	-1.0226	0.0097	0.0237	-0.0005	-30.6510

### 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	12.8140
Shear X	-5.6183
Shear Z	-0.0696
Moment X	-0.1772
Moment Y (Twist)	0.1703
Moment Z	58.8358

### 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	8.5769
Shear X	-3.3471
Shear Z	-0.0461
Moment X	-0.1175
Moment Y (Twist)	0.1143
Moment Z	35.0369

### 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	-0.0397	2.9217	0.0755	0.2081	-0.1979	0.4028
ULS: 2. D + L	-0.0397	2.9217	0.0755	0.2081	-0.1979	0.4028
ULS: 3. D + (S or Lr or R)	-0.1155	7.3788	0.2205	0.6079	-0.5775	1.1475
ULS: 3. D + (S or Lr or R)	-0.0397	2.9217	0.0755	0.2081	-0.1979	0.4028
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0965	6.2645	0.1842	0.5079	-0.4826	0.9613
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0397	2.9217	0.0755	0.2081	-0.1979	0.4028
ULS: 5b. D + 0.7E	-0.0397	2.9217	0.0755	0.2081	-0.1979	0.4028
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0965	6.2645	0.1842	0.5079	-0.4826	0.9613
ULS: 8. 0.6D + 0.7E	-0.0238	1.7530	0.0453	0.1249	-0.1187	0.2417
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.7797	7.5048	0.3205	0.8840	-0.9733	39.3361
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.7797	7.5048	0.3205	0.8840	-0.9733	39.3361
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9489	-0.7307	-0.1167	-0.3206	0.4101	-28.7678
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.4744	-0.1861	-0.0981	-0.2694	0.3608	-32.8918
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9015	9.7018	0.3680	1.0149	-1.0641	30.1613
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.9015	9.7018	0.3680	1.0149	-1.0641	30.1613
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1450	3.5252	0.0401	0.1114	-0.0265	-20.9166
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.7891	3.9337	0.0540	0.1498	-0.0635	-24.0096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.8447	6.3590	0.2592	0.7150	-0.7795	29.6028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.8447	6.3590	0.2592	0.7150	-0.7795	29.6028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2018	0.1824	-0.0687	-0.1884	0.2581	-21.4751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.8459	0.5909	-0.0547	-0.1500	0.2212	-24.5681

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.7638	6.3361	0.2903	0.8008	-0.8942	39.1750
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.7638	6.3361	0.2903	0.8008	-0.8942	39.1750
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.9648	-1.8994	-0.1469	-0.4039	0.4893	-28.9289
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.4903	-1.3548	-0.1283	-0.3526	0.4400	-33.0529

### 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	14.4610
Shear X	-6.3153
Shear Z	0.5770
Moment X	1.5932
Moment Y (Twist)	1.7363
Moment Z	66.7424

### 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	9.7018
Shear X	-3.7797
Shear Z	0.3680
Moment X	1.0149
Moment Y (Twist)	1.0641
Moment Z	39.3361

# Project Details

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

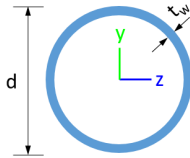


# Design Input Information

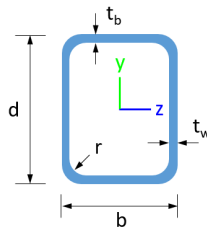
Design Factors			
$\Phi_t$	$\Phi_c$	$\Phi_b$	$\Phi_v$
0.9	0.9	0.9	0.9

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

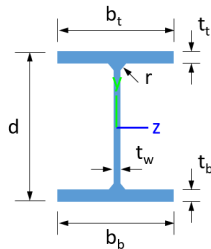
## Section Dimensions



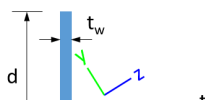
ID	Name	d (in)	$t_w$ (in)				
3	2in Pipe Sch 120	2.38	0.25				
6	4in Pipe Sch 120	4.50	0.44				
9	8in Pipe Sch 40	8.63	0.32				



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



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





103	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.1	30 0	20 0	1
104	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.59,1.67,1.67,1.68,1.67,1.67,1.67,1.6	30 0	20 0	1
105	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.6	30 0	20 0	1
106	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.1	30 0	20 0	1
107	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.6	30 0	20 0	1
108	20	1.33	1.33	2.0 5	1.75,1.75,1.75,1.75,1.75,1.75,1.75,1.75,1.75,1.79,2.22,1.75,1.75,1.78,1.26,1.75,1.75,1.72,1.83,1.75,1.75,1.8	30 0	20 0	1
109	3	2.60	2.60	4.0 0	-	30 0	20 0	1
110	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.6	30 0	20 0	1
111	20	1.33	1.33	2.0 5	2.00,2.01,2.00,2.02,2.00,2.00,2.07,2.07,2.08,2.10,2.07,2.07,2.07,2.09,2.06,2.06,1.87,1.57,2.06,2.06,2.0	30 0	20 0	1
112	6	1.30	1.30	2.0 0	-	30 0	20 0	1
113	20	4.88	4.00	7.5 0	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.0	30 0	20 0	1
114	20	4.88	4.00	7.5 0	1.07,1.07,1.07,1.08,1.07,1.07,1.08,1.08,1.08,1.51,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.0	30 0	20 0	1
115	20	10.2 0	10.2 0	10. 20	1.27,1.27,1.27,1.28,1.27,1.27,1.29,1.29,1.33,1.41,1.29,1.29,1.30,1.32,1.28,1.28,1.26,1.25,1.29,1.29,1.3	30 0	20 0	1
116	20	10.2 0	10.2 0	10. 20	1.25,1.26,1.25,1.26,1.25,1.25,1.26,1.26,1.27,1.67,1.26,1.26,1.27,1.39,1.26,1.26,1.25,1.26,1.26,1.26,1.2	30 0	20 0	1
150	34	5.67	5.67	5.6 7	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.1	30 0	20 0	25 0
151	34	5.67	5.67	5.6 7	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.1	30 0	20 0	25 0
152	34	5.67	5.67	5.6 7	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.1	30 0	20 0	25 0
153	34	5.67	5.67	5.6 7	1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.14,1.1	30 0	20 0	25 0
201	9	21.0 8	21.0 8	10. 04	-	30 0	20 0	1
202	6	1.30	1.30	2.0 0	-	30 0	20 0	1
203	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.1	30 0	20 0	1
204	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.60,1.67,1.67,1.68,1.67,1.67,1.67,1.6	30 0	20 0	1
205	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.6	30 0	20 0	1
206	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.1	30 0	20 0	1
207	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.6	30 0	20 0	1
208	20	1.33	1.33	2.0 5	2.17,2.19,2.17,2.20,2.18,2.17,2.23,2.23,2.38,1.72,2.24,2.24,2.34,1.22,2.22,2.22,2.11,2.41,2.22,2.22,2.4	30 0	20 0	1
209	3	2.60	2.60	4.0 0	-	30 0	20 0	1
210	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,1.59,1.67,1.67,1.68,1.67,1.67,1.67,1.6	30 0	20 0	1
211	20	1.33	1.33	2.0 5	2.32,2.32,2.32,2.31,2.32,2.32,2.28,2.28,2.21,2.08,2.27,2.27,2.26,2.19,2.29,2.29,2.38,2.04,2.28,2.28,2.1	30 0	20 0	1
212	6	1.30	1.30	2.0 0	-	30 0	20 0	1
213	20	4.88	4.00	7.5 0	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.0	30 0	20 0	1
214	20	4.88	4.00	7.5 0	1.07,1.07,1.07,1.08,1.07,1.07,1.08,1.08,1.08,1.51,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.08,1.08,1.08,1.0	30 0	20 0	1
215	20	10.2 0	10.2 0	10. 20	1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.12,1.13,1.13,1.12,1.12,1.12,1.13,1.12,1.12,1.11,1.10,1.12,1.12,1.1	30 0	20 0	1
---	--	10.2	10.2	10	1 10 1 10 1 10 1 10 1 10 1 10 1 10 1 11 1 20 1 10 1 10 1 11 1 06 1 10 1 10 1 10 1 11 1 10 1 10 1 1	30	20	-



10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	32.74	6.46	56.26	44.91
14	159.30	97.43	32.74	6.46	56.26	44.91
15	159.30	68.92	46.90	6.46	56.26	44.91
16	159.30	68.92	46.90	6.46	56.26	44.91
50	41.27	8.45	1.63	0.76	15.23	10.15
51	41.27	8.45	1.63	0.76	15.23	10.15
52	41.27	8.45	1.63	0.76	15.23	10.15
53	41.27	8.45	1.63	0.76	15.23	10.15
101	377.97	219.76	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	32.55	6.46	56.26	44.91
114	159.30	97.43	32.80	6.46	56.26	44.91
115	159.30	32.87	24.01	6.46	56.26	44.91
116	159.30	32.87	24.01	6.46	56.26	44.91
150	41.27	8.45	1.63	0.76	15.23	10.15
151	41.27	8.45	1.63	0.76	15.23	10.15
152	41.27	8.45	1.63	0.76	15.23	10.15
153	41.27	8.45	1.63	0.76	15.23	10.15
201	377.97	219.76	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	32.54	6.46	56.26	44.91
214	159.30	97.43	32.80	6.46	56.26	44.91
215	159.30	32.87	21.10	6.46	56.26	44.91
216	159.30	32.87	20.47	6.46	56.26	44.91
250	41.27	8.45	1.63	0.76	15.23	10.15
251	41.27	8.45	1.63	0.76	15.23	10.15
252	41.27	8.45	1.63	0.76	15.23	10.15
253	41.27	8.45	1.63	0.76	15.23	10.15
301	377.97	219.76	83.29	83.29	113.39	113.39

301	377.97	219.70	93.29	93.29	119.99	119.99
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	68.92	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	68.92	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	32.74	6.46	56.26	44.91
314	159.30	97.43	32.74	6.46	56.26	44.91
315	159.30	32.87	42.14	6.46	56.26	44.91
316	159.30	32.87	34.25	6.46	56.26	44.91
350	41.27	8.45	1.63	0.76	15.23	10.15
351	41.27	8.45	1.63	0.76	15.23	10.15
352	41.27	8.45	1.63	0.76	15.23	10.15
353	41.27	8.45	1.63	0.76	15.23	10.15

## 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	0.066	0.801	0.050	0.056	0.005	0.851	#13	0.431	Not Required	Pass
2	0.007	0.498	0.265	0.103	0.048	0.753	#13	0.054	Not Required	Pass
3	0.001	0.741	0.130	0.075	0.051	0.816	#13	0.046	Not Required	Pass
4	0.003	0.700	0.035	0.070	0.006	0.715	#13	0.122	Not Required	Pass
5	0.001	0.459	0.026	0.074	0.010	0.469	#13	0.076	Not Required	Pass
6	0.004	0.585	0.117	0.057	0.051	0.651	#21	0.046	Not Required	Pass
7	0.004	0.363	0.031	0.058	0.010	0.382	#13	0.076	Not Required	Pass
8	0.010	0.119	0.101	0.040	0.010	0.136	#21	0.102	Not Required	Pass
9	0.024	0.087	0.069	0.003	0.002	0.163	#13	0.137	Not Required	Pass
10	0.004	0.564	0.073	0.056	0.012	0.620	#13	0.122	Not Required	Pass
11	0.010	0.118	0.086	0.041	0.010	0.123	#13	0.068	Not Required	Pass
12	0.005	0.355	0.201	0.085	0.037	0.534	#13	0.054	Not Required	Pass
13	0.010	0.386	0.044	0.051	0.008	0.407	#13	0.204	Not Required	Pass
14	0.017	0.378	0.058	0.050	0.010	0.439	#13	0.306	Not Required	Pass
15	0.010	0.172	0.233	0.041	0.016	0.302	#21	0.357	Not Required	Pass
16	0.023	0.163	0.233	0.039	0.016	0.307	#21	0.357	Not Required	Pass
50	0.199	0.010	0.003	0.002	0.001	0.210	#21	0.783	Not Required	Pass
51	0.042	0.005	0.016	0.001	0.001	0.058	#21	0.522	Not Required	Pass
52	0.254	0.010	0.003	0.003	0.002	0.265	#23	0.783	Not Required	Pass
53	0.051	0.005	0.016	0.002	0.002	0.067	#23	0.522	Not Required	Pass
101	0.058	0.706	0.006	0.049	0.001	0.735	#13	0.431	Not Required	Pass
102	0.005	0.358	0.195	0.081	0.037	0.534	#13	0.054	Not Required	Pass
103	0.004	0.577	0.109	0.058	0.045	0.628	#21	0.046	Not Required	Pass
104	0.004	0.531	0.048	0.053	0.008	0.560	#13	0.082	Not Required	Pass
105	0.004	0.358	0.020	0.057	0.006	0.370	#13	0.076	Not Required	Pass
106	0.004	0.589	0.112	0.059	0.045	0.649	#21	0.046	Not Required	Pass
107	0.004	0.365	0.018	0.058	0.005	0.371	#13	0.076	Not Required	Pass

108	0.010	0.059	0.056	0.034	0.007	0.114	#21	0.102	Not Required	Pass
109	0.019	0.045	0.043	0.001	0.000	0.093	#13	0.137	Not Required	Pass
110	0.004	0.554	0.042	0.055	0.006	0.573	#13	0.082	Not Required	Pass
111	0.010	0.050	0.057	0.036	0.008	0.108	#21	0.068	Not Required	Pass
112	0.005	0.377	0.201	0.084	0.037	0.559	#13	0.054	Not Required	Pass
113	0.010	0.190	0.041	0.046	0.007	0.218	#13	0.204	Not Required	Pass
114	0.016	0.163	0.049	0.044	0.008	0.181	#21	0.306	Not Required	Pass
115	0.010	0.099	0.118	0.031	0.013	0.158	#21	0.520	Not Required	Pass
116	0.043	0.106	0.134	0.029	0.014	0.185	#21	0.780	Not Required	Pass
150	0.173	0.010	0.003	0.002	0.001	0.184	#21	0.783	Not Required	Pass
151	0.034	0.005	0.016	0.001	0.001	0.052	#23	0.522	Not Required	Pass
152	0.171	0.010	0.003	0.002	0.001	0.181	#24	0.783	Not Required	Pass
153	0.034	0.005	0.017	0.001	0.001	0.051	#24	0.522	Not Required	Pass
201	0.058	0.706	0.006	0.049	0.001	0.735	#13	0.431	Not Required	Pass
202	0.005	0.377	0.201	0.084	0.037	0.559	#13	0.054	Not Required	Pass
203	0.004	0.589	0.112	0.059	0.045	0.649	#21	0.046	Not Required	Pass
204	0.004	0.554	0.042	0.055	0.006	0.573	#13	0.082	Not Required	Pass
205	0.004	0.365	0.018	0.058	0.005	0.371	#13	0.076	Not Required	Pass
206	0.004	0.577	0.109	0.058	0.045	0.628	#21	0.046	Not Required	Pass
207	0.004	0.358	0.020	0.057	0.006	0.371	#13	0.076	Not Required	Pass
208	0.009	0.029	0.051	0.028	0.007	0.067	#24	0.102	Not Required	Pass
209	0.019	0.045	0.043	0.001	0.000	0.093	#13	0.137	Not Required	Pass
210	0.004	0.531	0.048	0.053	0.008	0.560	#13	0.082	Not Required	Pass
211	0.010	0.045	0.053	0.031	0.008	0.064	#24	0.068	Not Required	Pass
212	0.005	0.358	0.195	0.081	0.037	0.534	#13	0.054	Not Required	Pass
213	0.010	0.190	0.041	0.046	0.007	0.218	#13	0.204	Not Required	Pass
214	0.016	0.163	0.049	0.044	0.008	0.181	#21	0.306	Not Required	Pass
215	0.010	0.224	0.084	0.036	0.012	0.257	#21	0.520	Not Required	Pass
216	0.041	0.241	0.081	0.034	0.012	0.279	#21	0.780	Not Required	Pass
250	0.171	0.010	0.003	0.002	0.001	0.181	#24	0.783	Not Required	Pass
251	0.034	0.005	0.017	0.001	0.001	0.051	#24	0.522	Not Required	Pass
252	0.173	0.010	0.003	0.002	0.001	0.184	#21	0.783	Not Required	Pass
253	0.034	0.005	0.016	0.001	0.001	0.052	#23	0.522	Not Required	Pass
301	0.066	0.801	0.050	0.056	0.005	0.851	#13	0.431	Not Required	Pass
302	0.005	0.355	0.201	0.085	0.037	0.534	#13	0.054	Not Required	Pass
303	0.004	0.585	0.117	0.057	0.051	0.651	#21	0.046	Not Required	Pass
304	0.004	0.564	0.073	0.056	0.012	0.620	#13	0.122	Not Required	Pass
305	0.004	0.363	0.031	0.058	0.010	0.382	#13	0.076	Not Required	Pass
306	0.001	0.741	0.130	0.075	0.051	0.816	#13	0.046	Not Required	Pass
307	0.001	0.459	0.026	0.074	0.010	0.469	#13	0.076	Not Required	Pass
308	0.023	0.163	0.233	0.039	0.016	0.307	#21	0.535	Not Required	Pass
309	0.024	0.087	0.069	0.003	0.002	0.163	#13	0.137	Not Required	Pass
310	0.003	0.700	0.035	0.070	0.006	0.715	#13	0.122	Not Required	Pass
311	0.010	0.172	0.233	0.041	0.016	0.302	#21	0.357	Not Required	Pass
312	0.007	0.498	0.265	0.103	0.048	0.753	#13	0.054	Not Required	Pass
313	0.010	0.386	0.044	0.051	0.008	0.408	#13	0.204	Not Required	Pass
314	0.017	0.378	0.058	0.050	0.010	0.439	#13	0.306	Not Required	Pass
315	0.010	0.126	0.118	0.041	0.013	0.140	#21	0.520	Not Required	Pass
316	0.043	0.129	0.134	0.040	0.014	0.170	#21	0.780	Not Required	Pass
350	0.254	0.010	0.003	0.003	0.002	0.265	#23	0.783	Not Required	Pass
351	0.051	0.005	0.016	0.002	0.002	0.067	#23	0.522	Not Required	Pass
352	0.199	0.010	0.003	0.002	0.001	0.210	#21	0.783	Not Required	Pass

353	0.042	0.005	0.016	0.001	0.001	0.058	#21	0.522	Not Required	Pass
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## Definitions

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$\Phi_t$	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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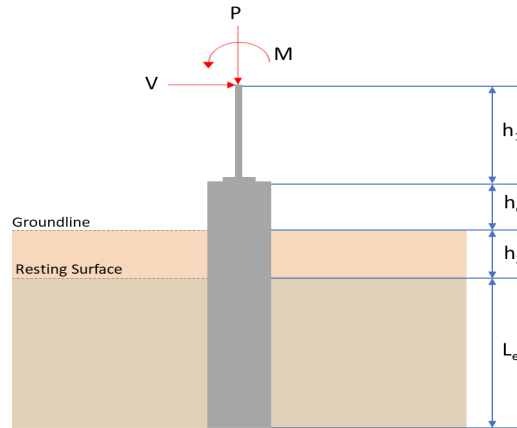
## SkyCiv Foundation Design

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

$L = 6.75$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

Load Component	ASD	LRFD
$P$ (kip)	8.577	12.814
$V_x$ (kip)	-3.347	-5.618
$V_z$ (kip)	0.046	0.070
$M_x$ (kipft)	0.118	0.177
$M_z$ (kipft)	35.037	58.836

### 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,

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

$$H_o = \frac{(-3.347 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.53296 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(35.037 \text{ kipft}) + ((-3.347 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.5791 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.2656 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.046 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0073248 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.118 \text{ kipft}) + ((0.046 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01879 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.2729 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2656 \text{ ft}), (1.2729 \text{ ft})]$$

$$L_{e,req} = 6.266 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.266 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.9283$$

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

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

$$q = \frac{(8.577 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.53606 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.53606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.26803$$

Status: **PASS**  
Ratio: **0.270**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.53296 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.5791 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.5791 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (5.5791 \text{ kipft/ft})) + (4 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6691 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.5791 \text{ kipft/ft})) + (3 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (5.5791 \text{ kipft/ft})) + (2 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.22909 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (5.5791 \text{ kipft/ft})) + ((-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.99566 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6691 \text{ ft})}{2}$$

$$p_a = 0.35018 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22909 \text{ kip/ft}^2)}{(0.35018 \text{ kip/ft}^2)}$$

$$Ratio = 0.6542$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$

$$p_s = 1.0125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.99566 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.98337$$

Status: **PASS**  
Ratio: **0.650**

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

#### Considering z-direction:

$H_o = 0.0073248 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.01879 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.01879 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.01879 \text{ kipft/ft})) + (4 \times (0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8583 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.01879 \text{ kipft/ft})) + (3 \times (0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.01879 \text{ kipft/ft})) + (2 \times (0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.0052956 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.01879 \text{ kipft/ft})) + ((0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.01146 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8583 \text{ ft})}{2}$$

$$p_a = 0.36437 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0052956 \text{ kip/ft}^2)}{(0.36437 \text{ kip/ft}^2)}$$

$$Ratio = 0.014534$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$

$$p_s = 1.0125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

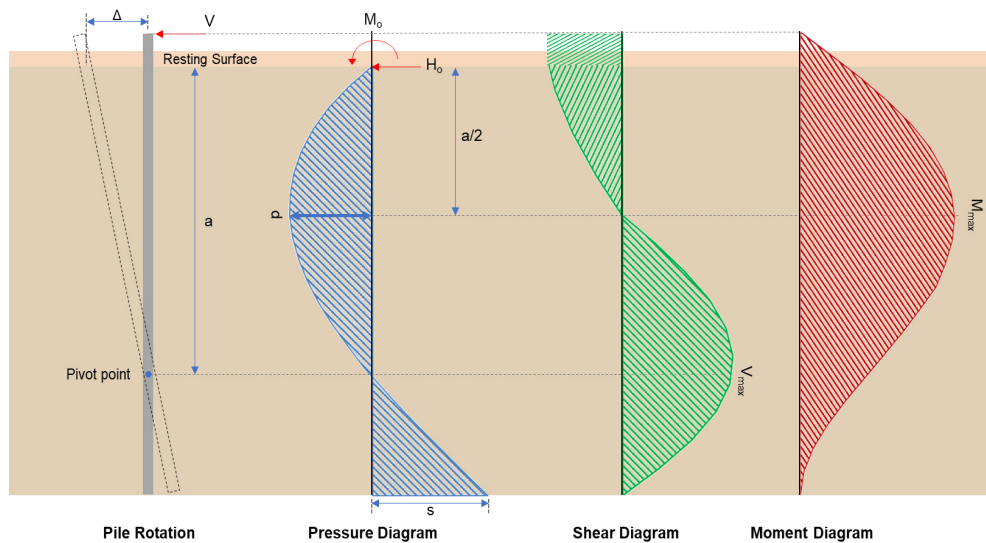
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.01146 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.011318$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.618 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.89459 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(58.836 \text{ kipft}) + ((-5.618 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3688 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.3688 \text{ kipft/ft})}{(-0.89459 \text{ kip/ft})}$$

$$E = 10.473 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.3688 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (9.3688 \text{ kipft/ft})) + (4 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = \frac{(-0.89459 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (9.3688 \text{ kipft/ft})) + (4 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6691 \text{ ft}$$

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

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

$$V_{max} = ((-0.89459 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6691 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6691 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.184 \text{ kip}$$

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

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

$$M_{max} = ((-0.89459 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(10.473 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 38.93 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.07 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.011146 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.177 \text{ kipft}) + ((0.07 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.028185 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.028185 \text{ kipft/ft})}{(0.011146 \text{ kip/ft})}$$

$$E = 2.5286 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.028185 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.011146 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.028185 \text{ kipft/ft})) + (4 \times (0.011146 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8601 \text{ ft}$$

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

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

$$V_{max} = ((0.011146 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8601 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8601 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.059393 \text{ kip}$$

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

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

$$M_{max} = ((0.011146 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(2.5286 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.17371 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.814 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.17 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.17 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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} = \text{Min spacing of reinforcement,}</math></p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties}</math> - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p><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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio - Capacity</i></p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(12.814 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.00479$	<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> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p><math>\lambda_s</math> - size effect modification factor</p> $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula <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> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.814 \text{ kip} \rightarrow 12814 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(12814 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.19 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.19 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.19 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.19 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.21 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 12,184 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.184 \text{ kip})}{(111.21 \text{ kip})}$$

$$Ratio = 0.10956$$

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

**Considering z-direction:**

$V_{max} = 0.059393 \text{ kip}$  - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.059393 \text{ kip})}{(111.21 \text{ kip})}$$

$$Ratio = 0.00053408$$

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  $\phi M_{n,2}$

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

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

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

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:**

$M_{max} = 38.93 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(38.93 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.15597$$

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

**Considering z-direction:**

$M_{max} = 0.17371 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.17371 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00069595$$

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

REFERENCES	CALCULATIONS	RESULTS
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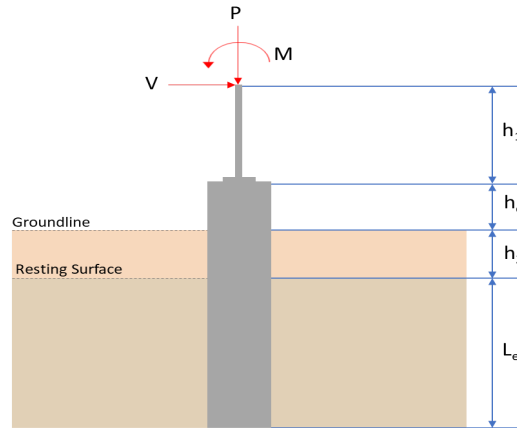
## SkyCiv Foundation Design

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

$L = 6.75$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

Load Component	ASD	LRFD
$P$ (kip)	8.577	12.814
$V_x$ (kip)	-3.347	-5.618
$V_z$ (kip)	-0.046	-0.070
$M_x$ (kipft)	-0.118	-0.177
$M_z$ (kipft)	35.037	58.836

### 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,

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

$$H_o = \frac{(-3.347 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.53296 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(35.037 \text{ kipft}) + ((-3.347 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.5791 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.2656 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.046 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0073248 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.118 \text{ kipft}) + ((-0.046 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01879 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.0183 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2656 \text{ ft}), (1.0183 \text{ ft})]$$

$$L_{e,req} = 6.266 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.75 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.266 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.9283$$

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

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

$$q = \frac{(8.577 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.53606 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.53606 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.26803$$

Status: **PASS**  
Ratio: **0.270**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.53296 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.5791 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.5791 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (5.5791 \text{ kipft/ft})) + (4 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6691 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.5791 \text{ kipft/ft})) + (3 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (5.5791 \text{ kipft/ft})) + (2 \times (-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.22909 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (5.5791 \text{ kipft/ft})) + ((-0.53296 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.99566 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6691 \text{ ft})}{2}$$

$$p_a = 0.35018 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22909 \text{ kip/ft}^2)}{(0.35018 \text{ kip/ft}^2)}$$

$$Ratio = 0.6542$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$

$$p_s = 1.0125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.99566 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.98337$$

Status: **PASS**  
Ratio: **0.650**

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

#### Considering z-direction:

$H_o = -0.0073248 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.01879 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.01879 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.01879 \text{ kipft/ft})) + (4 \times (-0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8583 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.01879 \text{ kipft/ft})) + (3 \times (-0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.01879 \text{ kipft/ft})) + (2 \times (-0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = -0.0020728 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.01879 \text{ kipft/ft})) + ((-0.0073248 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = -0.0015622 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8583 \text{ ft})}{2}$$

$$p_a = 0.36437 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.0020728 \text{ kip/ft}^2)}{(0.36437 \text{ kip/ft}^2)}$$

$$Ratio = -0.0056887$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$$

$$p_s = 1.0125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

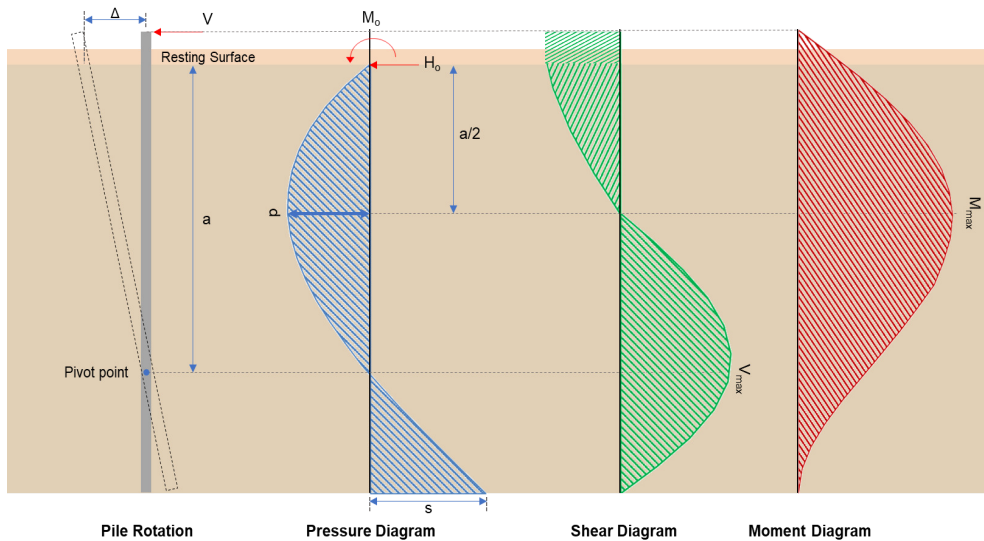
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(-0.0015622 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = -0.0015429$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.618 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.89459 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(58.836 \text{ kipft}) + ((-5.618 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3688 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.3688 \text{ kipft/ft})}{(-0.89459 \text{ kip/ft})}$$

$$E = 10.473 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.3688 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (9.3688 \text{ kipft/ft})) + (4 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = \frac{(-0.89459 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (9.3688 \text{ kipft/ft})) + (4 \times (-0.89459 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6691 \text{ ft}$$

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

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

$$V_{max} = ((-0.89459 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6691 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6691 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.184 \text{ kip}$$

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

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

$$M_{max} = ((-0.89459 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(10.473 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (10.473 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6691 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 38.93 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.07 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.011146 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.177 \text{ kipft}) + ((-0.07 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.028185 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.028185 \text{ kipft/ft})}{(-0.011146 \text{ kip/ft})}$$

$$E = 2.5286 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.028185 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.011146 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.028185 \text{ kipft/ft})) + (4 \times (-0.011146 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8601 \text{ ft}$$

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

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

$$V_{max} = ((-0.011146 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8601 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8601 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.059393 \text{ kip}$$

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

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

$$M_{max} = ((-0.011146 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(2.5286 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.5286 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8601 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.17371 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\left( \frac{12.814 \text{ kip}}{(0.65) \times (0.8)} \right) - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.17 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.17 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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} = \text{Min spacing of reinforcement,}</math></p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> <p>Since longitudinal reinforcement is <math>\leq</math> No. 10: Use #3(0.375 in)</p> <p><math>s_{ties}</math> - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p><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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(12.814 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.00479$	<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> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p><math>\lambda_s</math> - size effect modification factor</p> $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula <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> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.814 \text{ kip} \rightarrow 12814 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(12814 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.19 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.19 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.19 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.19 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.21 \text{ kip}$$

**Considering x-direction:**

$V_{max}$  = 12.184 kip - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(12.184 \text{ kip})}{(111.21 \text{ kip})}$$

$$Ratio = 0.10956$$

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

**Considering z-direction:**

$V_{max} = 0.059393 \text{ kip}$  - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.059393 \text{ kip})}{(111.21 \text{ kip})}$$

$$Ratio = 0.00053408$$

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:**

$M_{max} = 38.93 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(38.93 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.15597$$

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

**Considering z-direction:**

$M_{max} = 0.17371 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.17371 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00069595$$

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

REFERENCES	CALCULATIONS	RESULTS
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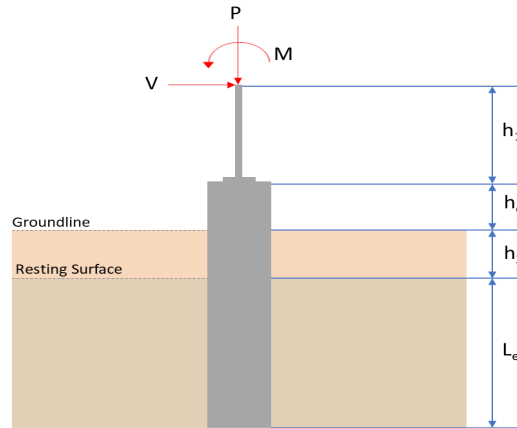
## SkyCiv Foundation Design

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

$L = 7$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

Load Component	ASD	LRFD
$P$ (kip)	9.702	14.461
$V_x$ (kip)	-3.780	-6.315
$V_z$ (kip)	-0.368	-0.577
$M_x$ (kipft)	-1.015	-1.593
$M_z$ (kipft)	39.336	66.742

### 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,

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

$$H_o = \frac{(-3.78 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.60191 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(39.336 \text{ kipft}) + ((-3.78 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.2637 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.4489 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.368 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.058599 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.015 \text{ kipft}) + ((-0.368 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.16162 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.8568 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = MAX[(6.4489 \text{ ft}), (1.8568 \text{ ft})]$$

$$L_{e,req} = 6.449 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$Ratio = \frac{(6.449 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.92129$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(9.702 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.60638 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.60638 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.30319$$

Status: **PASS**  
Ratio: **0.300**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.60191 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 6.2637 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (6.2637 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (6.2637 \text{ kipft/ft})) + (4 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8473 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.2637 \text{ kipft/ft})) + (3 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (6.2637 \text{ kipft/ft})) + (2 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.22761 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (6.2637 \text{ kipft/ft})) + ((-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.018 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8473 \text{ ft})}{2}$$

$$p_a = 0.36355 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22761 \text{ kip/ft}^2)}{(0.36355 \text{ kip/ft}^2)}$$

$$Ratio = 0.62609$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.018 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.96956$$

Status: **PASS**  
Ratio: **0.630**

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

#### Considering z-direction:

$H_o = -0.058599 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.16162 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.16162 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.058599 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.16162 \text{ kipft/ft})) + (4 \times (-0.058599 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0333 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.16162 \text{ kipft/ft})) + (3 \times (-0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.16162 \text{ kipft/ft})) + (2 \times (-0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = -0.015563 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.16162 \text{ kipft/ft})) + ((-0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = -0.010646 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0333 \text{ ft})}{2}$$

$$p_a = 0.3775 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.015563 \text{ kip/ft}^2)}{(0.3775 \text{ kip/ft}^2)}$$

$$Ratio = -0.041227$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

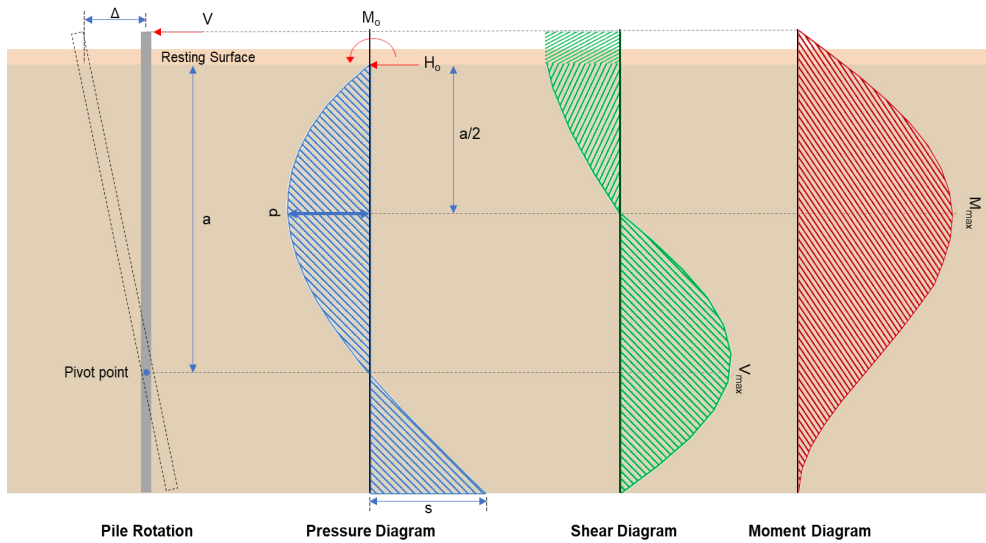
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(-0.010646 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = -0.010139$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-6.315 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.0056 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(66.742 \text{ kipft}) + ((-6.315 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.628 \text{ kipft/ft}$$

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

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

$$E = \frac{(10.628 \text{ kipft/ft})}{(-1.0056 \text{ kip/ft})}$$

$$E = 10.569 \text{ ft}$$

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

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

$$a = \frac{(4 \times (10.628 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft})^2)}{6 \times (10.628 \text{ kipft/ft}) + 4 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft})}$$

$$a = \frac{(6 \times (10.628 \text{ kipft/ft})) + (4 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft}))}{}$$

$$a = 4.8453 \text{ ft}$$

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

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

$$V_{max} = ((-1.0056 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.8453 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.8453 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 13.398 \text{ kip}$$

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

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

$$M_{max} = ((-1.0056 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(10.569 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 44.342 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.577 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.091879 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.593 \text{ kipft}) + ((-0.577 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.25366 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.25366 \text{ kipft/ft})}{(-0.091879 \text{ kip/ft})}$$

$$E = 2.7608 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.25366 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.091879 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.25366 \text{ kipft/ft})) + (4 \times (-0.091879 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0332 \text{ ft}$$

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

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

$$V_{max} = ((-0.091879 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(5.0332 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(5.0332 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.50225 \text{ kip}$$

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

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

$$M_{max} = ((-0.091879 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(2.7608 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.5291 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(14.461 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.116 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.116 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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. 10<math>\emptyset</math>: Use #3(0.375 in)</p> <p>25.7.2.1 <math>s_{ties}</math> - Maximum spacing of ties,</p>	$Ratio = 0.96556$ $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p><b>Ties:</b></p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p><b>Summary:</b></p> <p>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> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>Ratio - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(14.461 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0054056$	<p>Status: <b>PASS</b> Ratio: <b>0.010</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> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>,</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 14.461 \text{ kip} \rightarrow 14461 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(14461 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.41 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.41 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.41 \text{ kip}$$

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

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

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

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

$A_v$  - Ties rebar area,

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

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

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

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

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

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

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

$V_s$  - Governing shear strength of steel

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

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

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

22.5.1.1  $\phi V_n$  - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.41 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.35 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 13.398 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(13.398 \text{ kip})}{(111.35 \text{ kip})}$$

$$Ratio = 0.12033$$

Status: **PASS**  
Ratio: **0.120**

**Considering z-direction:**

$V_{max} = 0.50225 \text{ kip}$  - Maximum shear force in the z-direction,  
Ratio - Capacity

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

$$Ratio = \frac{(0.50225 \text{ kip})}{(111.35 \text{ kip})}$$

$$Ratio = 0.0045106$$

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:**

$M_{max} = 44.342 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(44.342 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.17765$$

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

**Considering z-direction:**

$M_{max} = 1.5291 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(1.5291 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0061263$$

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

REFERENCES	CALCULATIONS	RESULTS
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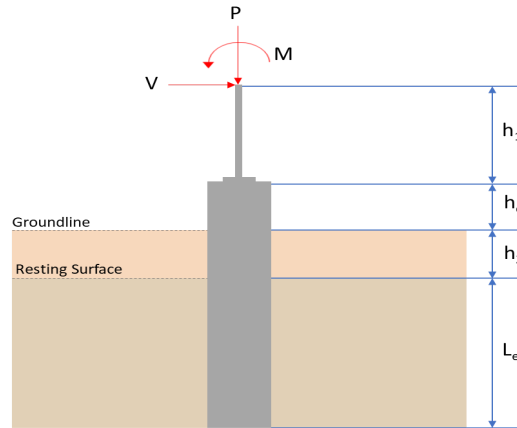
## SkyCiv Foundation Design

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

$L = 7$  ft - Total pile length

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

$h_2 = 0$  ft - Depth to resisting surface

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

### Tabulation of Soil Parameters

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

### Tabulation of Loads

Load Component	ASD	LRFD
$P$ (kip)	9.702	14.461
$V_x$ (kip)	-3.780	-6.315
$V_z$ (kip)	0.368	0.577
$M_x$ (kipft)	1.015	1.593
$M_z$ (kipft)	39.336	66.742

### 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,

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

$$H_o = \frac{(-3.78 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.60191 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(39.336 \text{ kipft}) + ((-3.78 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.2637 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 6.4489 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.368 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.058599 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.015 \text{ kipft}) + ((0.368 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.16162 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.8404 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.4489 \text{ ft}), (2.8404 \text{ ft})]$$

$$L_{e,req} = 6.449 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.449 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.92129$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(9.702 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.60638 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.60638 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.30319$$

Status: **PASS**  
Ratio: **0.300**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.60191 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 6.2637 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (6.2637 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (6.2637 \text{ kipft/ft})) + (4 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8473 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.2637 \text{ kipft/ft})) + (3 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (6.2637 \text{ kipft/ft})) + (2 \times (-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.22761 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (6.2637 \text{ kipft/ft})) + ((-0.60191 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.018 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8473 \text{ ft})}{2}$$

$$p_a = 0.36355 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.22761 \text{ kip/ft}^2)}{(0.36355 \text{ kip/ft}^2)}$$

$$Ratio = 0.62609$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.018 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.96956$$

Status: **PASS**  
Ratio: **0.630**

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

#### Considering z-direction:

$H_o = 0.058599 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.16162 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.16162 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.058599 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.16162 \text{ kipft/ft})) + (4 \times (0.058599 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0333 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.16162 \text{ kipft/ft})) + (3 \times (0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.16162 \text{ kipft/ft})) + (2 \times (0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.041317 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.16162 \text{ kipft/ft})) + ((0.058599 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.089809 \text{ kip/ft}^2$$

#### Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.0333 \text{ ft})}{2}$$

$$p_a = 0.3775 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.041317 \text{ kip/ft}^2)}{(0.3775 \text{ kip/ft}^2)}$$

$$Ratio = 0.10945$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

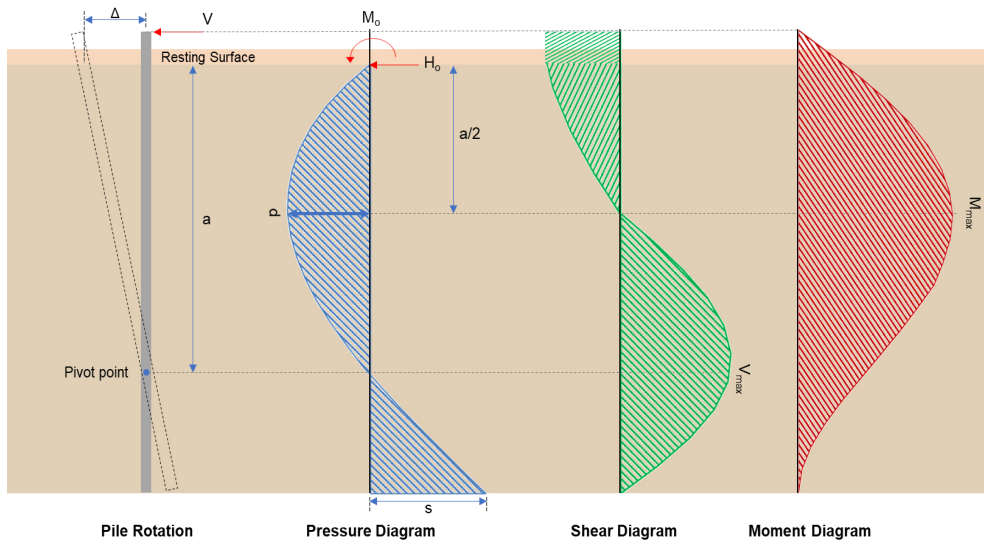
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.089809 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.085532$$

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

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-6.315 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.0056 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(66.742 \text{ kipft}) + ((-6.315 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.628 \text{ kipft/ft}$$

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

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

$$E = \frac{(10.628 \text{ kipft/ft})}{(-1.0056 \text{ kip/ft})}$$

$$E = 10.569 \text{ ft}$$

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

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

$$a = \frac{(4 \times (10.628 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft})^2)}{6 \times (10.628 \text{ kipft/ft}) + 4 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft})}$$

$$a = \frac{(6 \times (10.628 \text{ kipft/ft})) + (4 \times (-1.0056 \text{ kip/ft}) \times (7 \text{ ft}))}{}$$

$$a = 4.8453 \text{ ft}$$

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

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

$$V_{max} = ((-1.0056 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.8453 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.8453 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 13.398 \text{ kip}$$

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

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

$$M_{max} = ((-1.0056 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(10.569 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 44.342 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.577 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.091879 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.593 \text{ kipft}) + ((0.577 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.25366 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.25366 \text{ kipft/ft})}{(0.091879 \text{ kip/ft})}$$

$$E = 2.7608 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.25366 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.091879 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.25366 \text{ kipft/ft})) + (4 \times (0.091879 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0332 \text{ ft}$$

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

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

$$V_{max} = ((0.091879 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(5.0332 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[ 4 \times \left( \frac{3 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(5.0332 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.50225 \text{ kip}$$

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

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

$$M_{max} = ((0.091879 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(2.7608 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right) \right. \\ \left. - \left[ \left( \frac{4 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.7608 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(5.0332 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.5291 \text{ kipft}$$

### 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,  $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(14.461 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.116 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.116 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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{(14.461 \text{ kip})}{(2675.2 \text{ kip})}</math></p> <p style="text-align: center;"><math>Ratio = 0.0054056</math></p>	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p><b>Shear Strength (ACI 318-19, LRFD)</b></p> <p><b>Parameters:</b></p> <p><math>b_w = 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  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 14.461 \text{ kip} \rightarrow 14461 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(14461 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.41 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.41 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.41 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.41 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.35 \text{ kip}$$

**Considering x-direction:**

$V_{max} = 13.398 \text{ kip}$  - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(13.398 \text{ kip})}{(111.35 \text{ kip})}$$

$$Ratio = 0.12033$$

Status: **PASS**  
Ratio: **0.120**

**Considering z-direction:**

$V_{max} = 0.50225 \text{ kip}$  - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.50225 \text{ kip})}{(111.35 \text{ kip})}$$

$$Ratio = 0.0045106$$

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:**

$M_{max} = 44.342 \text{ kipft}$  - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(44.342 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.17765$$

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

**Considering z-direction:**

$M_{max} = 1.5291 \text{ kipft}$  - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(1.5291 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0061263$$

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