

# Your Project Calculations



Project Name: UnivofMNMorris-JB-RevE

S3D Model Link:  
[https://platform.skyciv.com/structural?preload\\_name=UnivofMNMorris-JB-RevE&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/9\\_2023](https://platform.skyciv.com/structural?preload_name=UnivofMNMorris-JB-RevE&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023)

Public Model Link:  
[https://platform.skyciv.com/structural-viewer?project\\_id=iliHIKtaWIPYyWfjmHU63DrLLk1PFXS81KexEuGrOiGVCUWehMhyhXNk8ZBSIZm](https://platform.skyciv.com/structural-viewer?project_id=iliHIKtaWIPYyWfjmHU63DrLLk1PFXS81KexEuGrOiGVCUWehMhyhXNk8ZBSIZm)

## Array Specification

<b>Product:</b>	Beam
<b>Unique ID:</b>	3P-22.5-6TOP-XD-45-L-4Hx8W-JA8J
<b>Duty Classification:</b>	XD
<b>Module Width:</b>	44.65 in
<b>Module Length:</b>	89.72in
<b>Number of Rows:</b>	4
<b>Number of Columns:</b>	8
<b>Total Number of Modules:</b>	32
<b>Desired Tilt Angle:</b>	30
<b>Front Edge Clearance:</b>	8
<b>Total Array Height at Tilt:</b>	15.48 ft
<b>Total Frame Length:</b>	60.00 ft
<b>Frame Weight:</b>	3267 lbs
<b>Array Dimensions N/S:</b>	15.05 ft
<b>Array Dimensions E/W:</b>	60.48 ft
<b>Rail Length:</b>	180.60 in
<b>Rail Spacing:</b>	3.78 ft
<b>Rail Check:</b>	PASS (56% utilized)

## Support Specifications

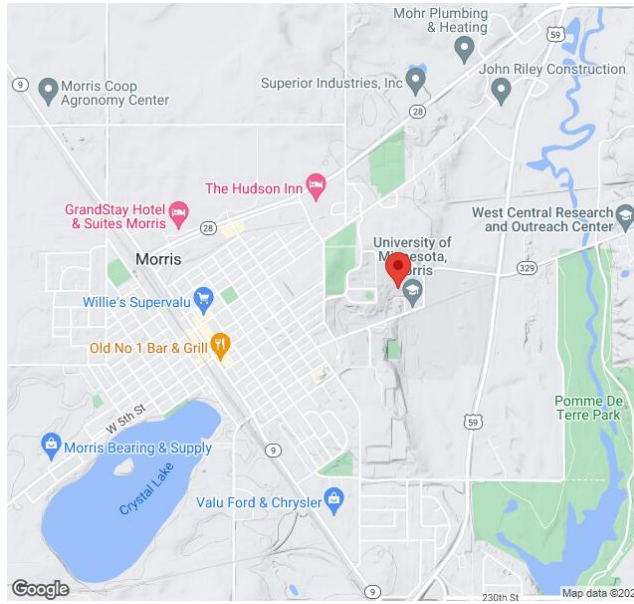
<b>Pole Size:</b>	6in Pipe Sch 80
<b>Pole Length above Grade:</b>	11.76 ft
<b>Number of Poles:</b>	3
<b>Pole Spacing:</b>	22.5 ft

## Foundation Specifications

<b>Foundation Type:</b>	Square
<b>Foundation Dimensions:</b>	48 x 48 in
<b>Foundation Depth (below grade):</b>	Pile 1: 6.25 ft Pile 2: 6.50 ft Pile 3: 6.25 ft
<b>Foundation Volume:</b>	11.259 y <sup>3</sup>
<b>Foundation Result:</b>	PASSED
<b>Mount Twist:</b>	0.601330 kip

## Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	B
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	600 E 4th St, Morris, MN 56267, USA
<b>Wind Speed:</b>	104 mph
<b>Snow Load:</b>	50 psf
<b>Design Uplift Pressure:</b>	Multiple pressures
<b>Design Downforce Pressure:</b>	Multiple pressures
<b>Design Snow Pressure:</b>	0.021993 ksf



### Design Disclaimer

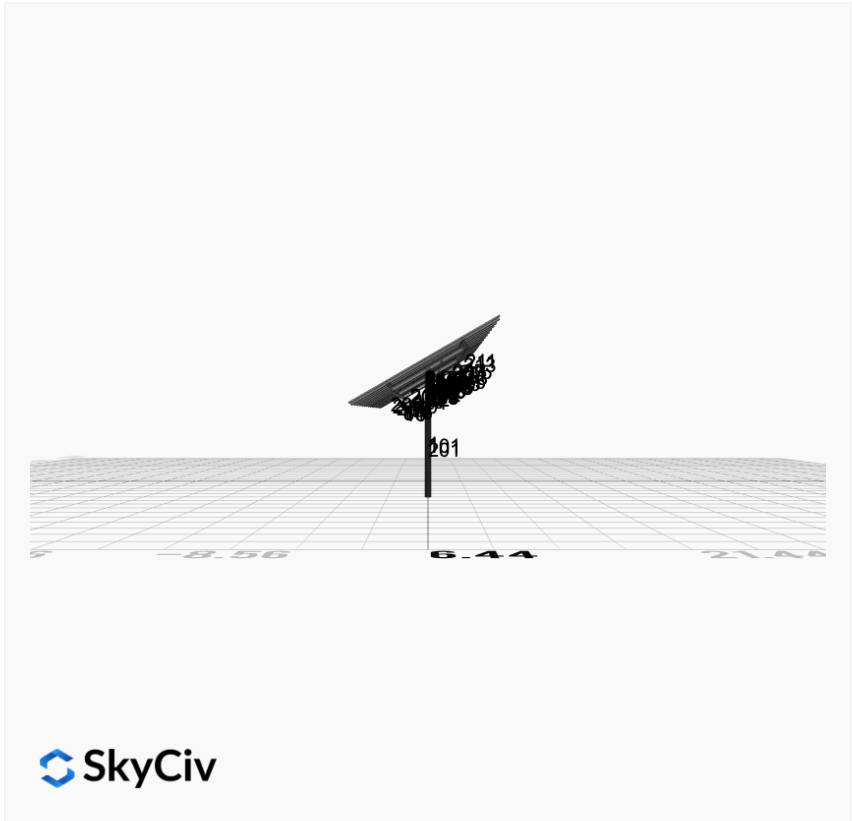
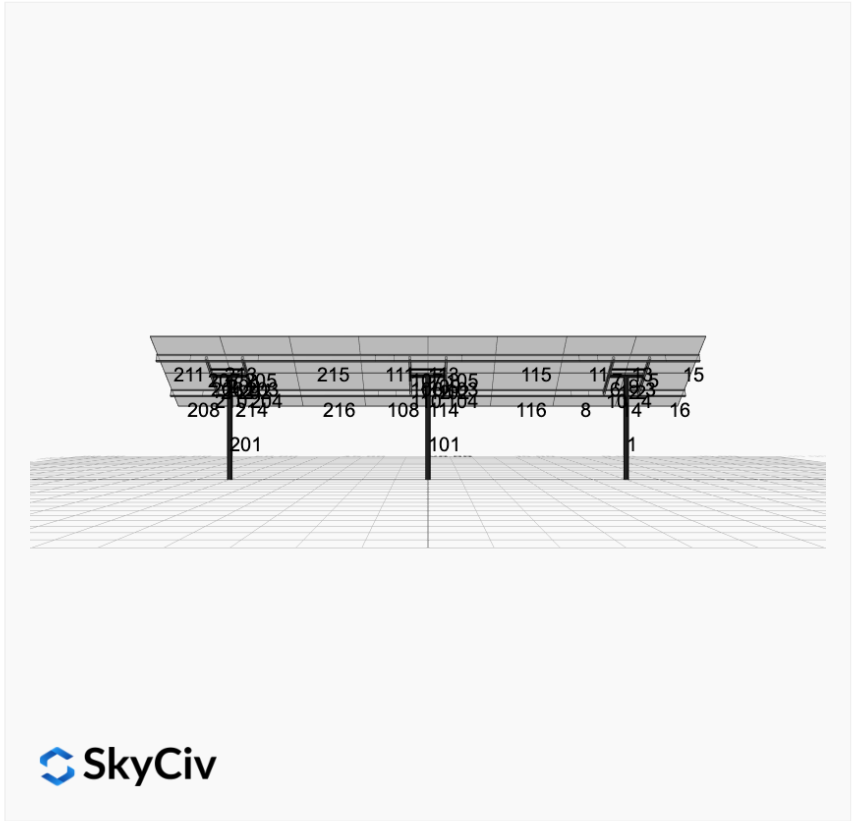
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

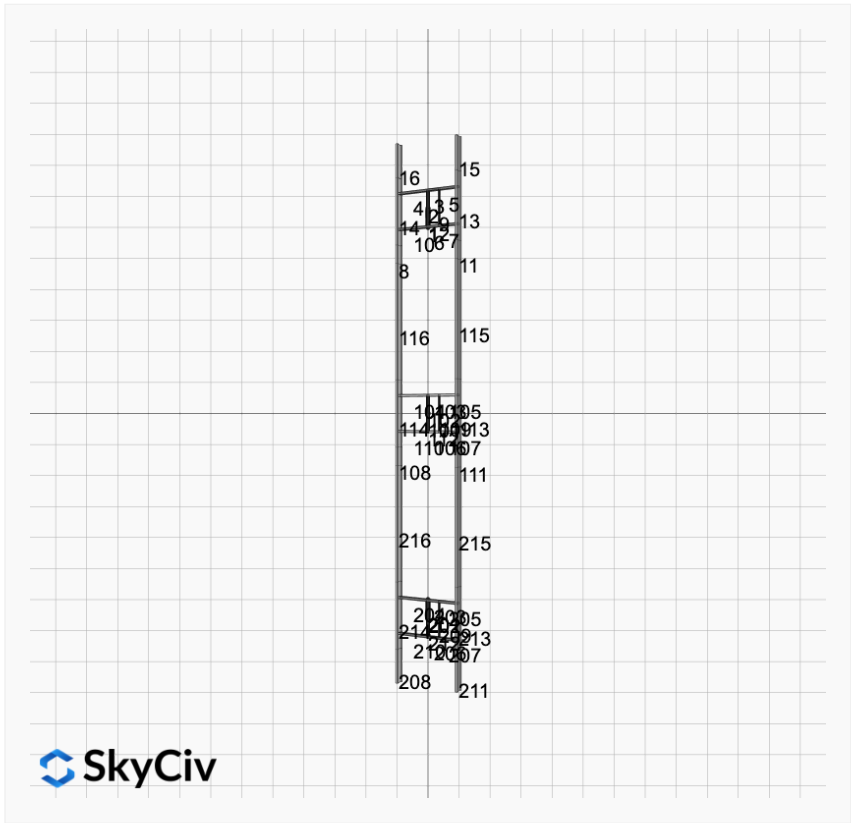
### AutoDesigner Input

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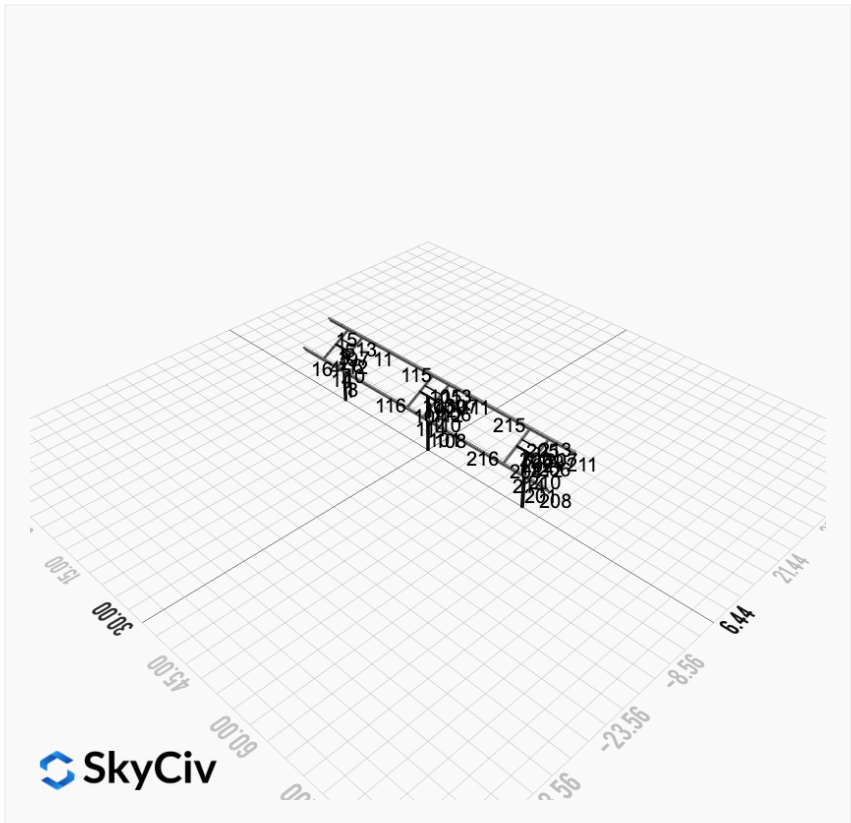
### Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles

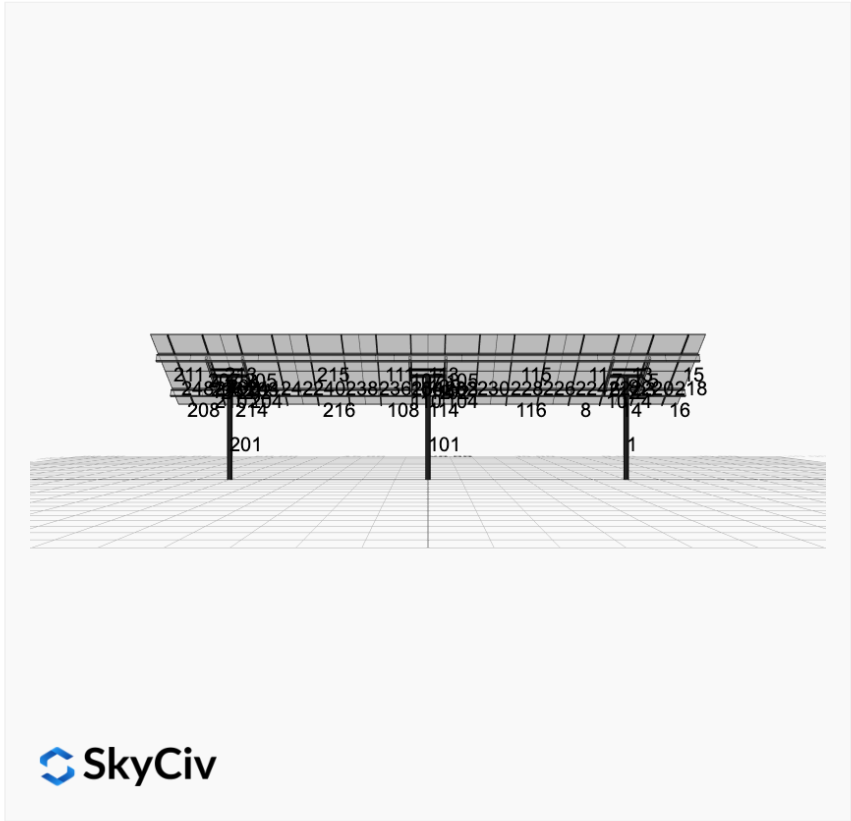




SkyCiv

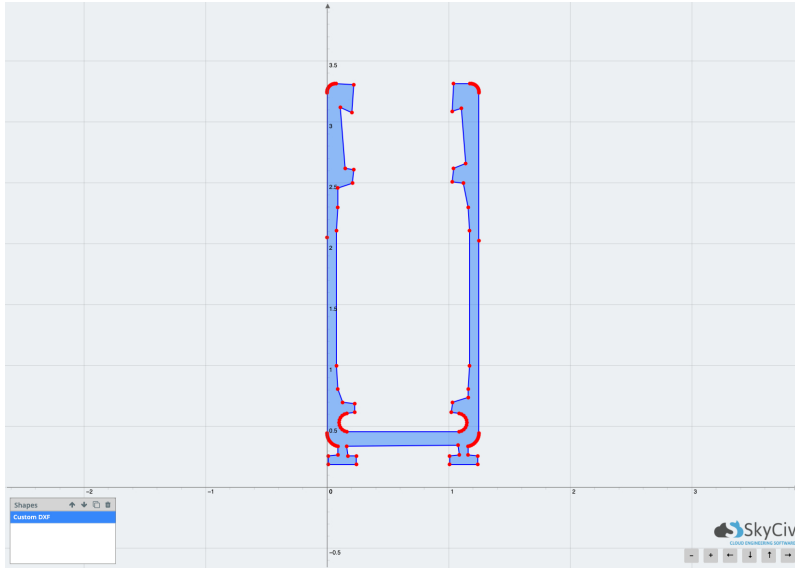


SkyCiv



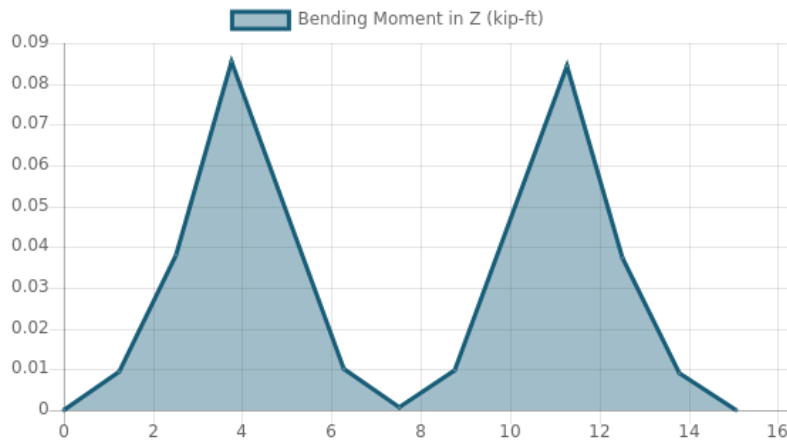
### Rail Design Check

**Rail Length:** 15.049999999999999 ft  
**Additional Restraints Required:** None  
**Tributary Width:** 3.78 ft  
**Material:** Aluminium  
**Density:** 169 lb/ft<sup>3</sup>  
**Elasticity Modulus:** 10000 ksi  
**Fy:** 34.5 ksi  
**Fu:** 37 ksi  
**Snow (X):** 0.0720 kip/ft  
**Snow (Y):** -0.0416 kip/ft  
**Wind uplift Case A:** 0.0751 kip/ft  
**Wind uplift Case A:** 0.0751 kip/ft  
**Wind uplift Case B (X):** 0.0000 kip/ft  
**Wind uplift Case B (Y):** 0.1043 kip/ft

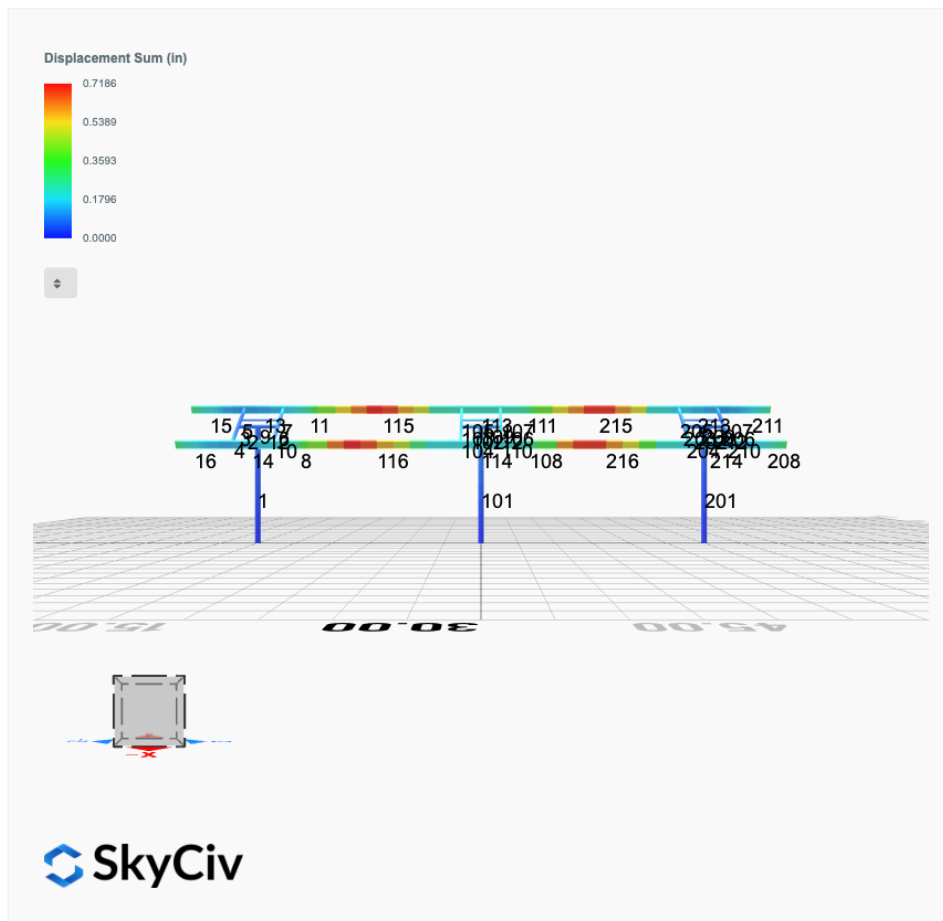


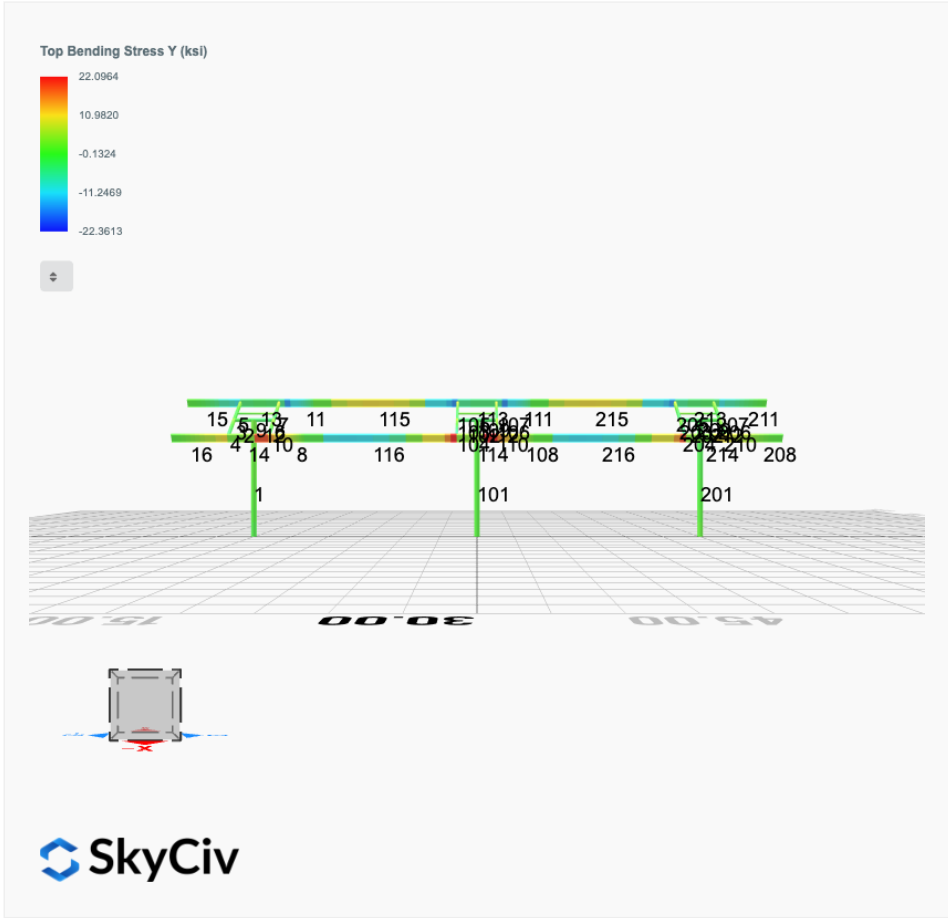
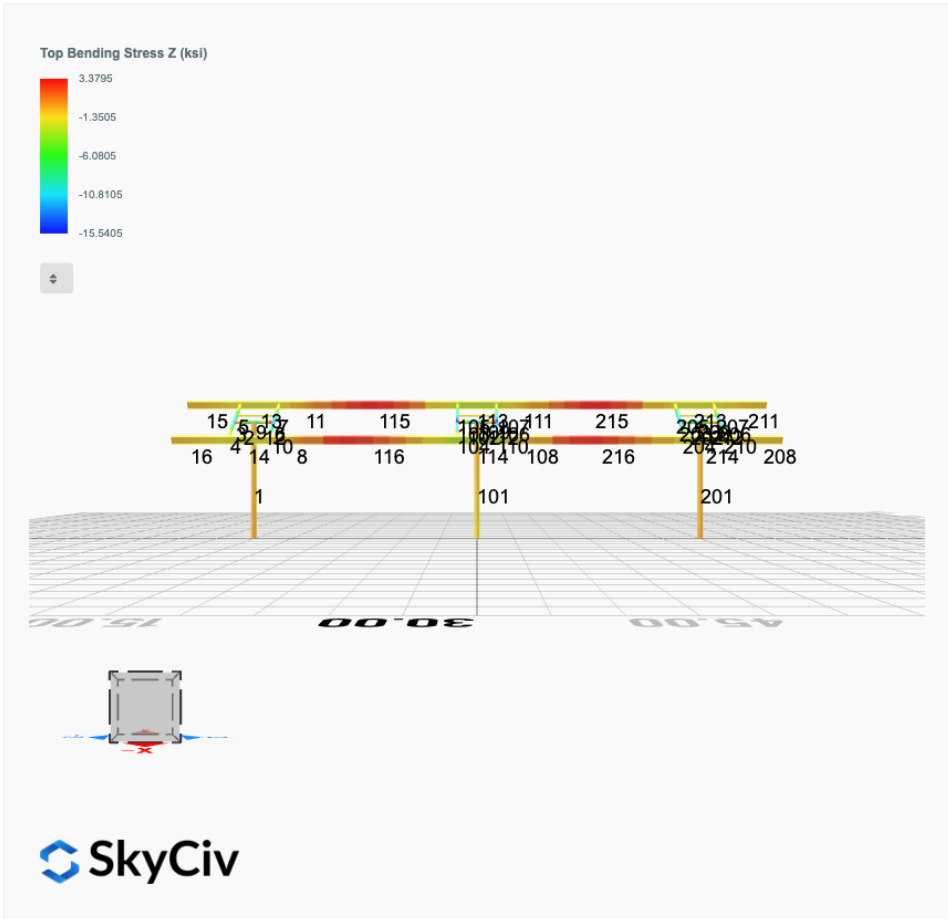
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	19.16725575	0.556	PASS
Material Yield	34.5	19.16725575	0.556	PASS
Material Strength	37	19.16725575	0.518	PASS

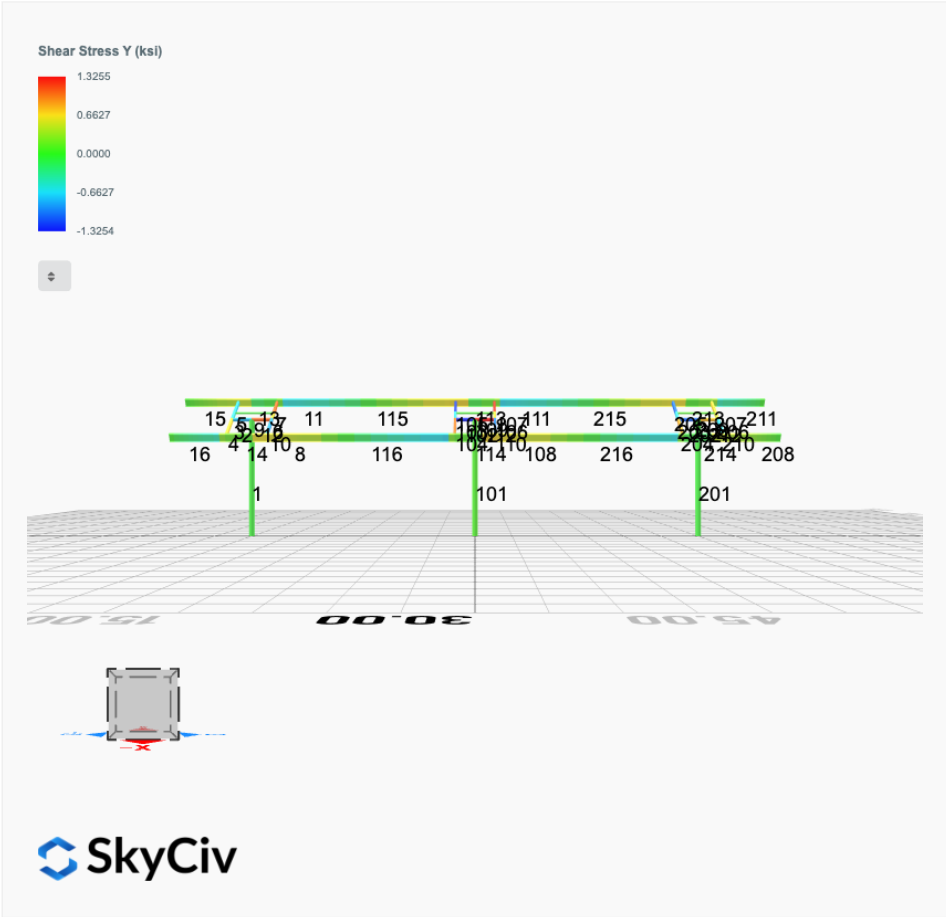
Member 1, ULS: 1. 1.4D

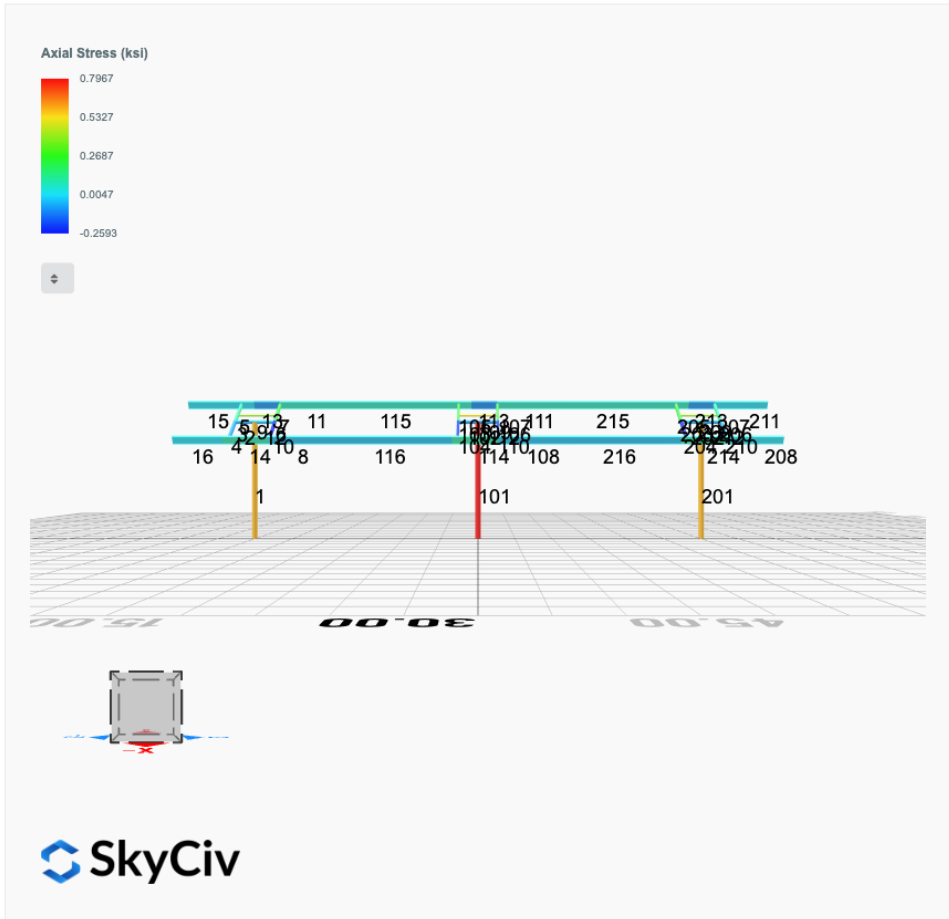


## FEM Results (Envelope Worst Case for each member)









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

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0188	2.3066	0.0539	0.2012	-0.0343	-0.1547
ULS: 2. D + L	0.0188	2.3066	0.0539	0.2012	-0.0343	-0.1547
ULS: 3. D + (S or Lr or R)	0.0766	7.5579	0.2217	0.8302	-0.1420	-0.7027
ULS: 3. D + (S or Lr or R)	0.0188	2.3066	0.0539	0.2012	-0.0343	-0.1547
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0621	6.2451	0.1798	0.6730	-0.1151	-0.5657
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.3066	0.0539	0.2012	-0.0343	-0.1547
ULS: 5b. D + 0.7E	0.0188	2.3066	0.0539	0.2012	-0.0343	-0.1547
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0621	6.2451	0.1798	0.6730	-0.1151	-0.5657
ULS: 8. 0.6D + 0.7E	0.0113	1.3840	0.0323	0.1207	-0.0206	-0.0928
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9553	5.6702	0.2191	0.8071	-0.3304	24.1412
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9553	5.6702	0.2191	0.8071	-0.3304	24.1412
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7052	-0.5706	-0.0816	-0.2928	0.2082	-19.6865
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4461	-0.1120	-0.0800	-0.2869	0.2081	-23.6099
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4184	8.7678	0.3037	1.1274	-0.3371	17.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4184	8.7678	0.3037	1.1274	-0.3371	17.6563
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3269	4.0872	0.0782	0.3025	0.0668	-15.2145
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1326	4.4312	0.0794	0.3069	0.0667	-18.1571
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4618	4.8293	0.1778	0.6556	-0.2564	18.0673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4618	4.8293	0.1778	0.6556	-0.2564	18.0673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2836	0.1487	-0.0477	-0.1693	0.1476	-14.8035
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0893	0.4927	-0.0465	-0.1649	0.1475	-17.7461
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9628	4.7476	0.1976	0.7266	-0.3167	24.2031
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9628	4.7476	0.1976	0.7266	-0.3167	24.2031
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6977	-1.4932	-0.1031	-0.3733	0.2219	-19.6246
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4386	-1.0346	-0.1015	-0.3674	0.2218	-23.5480

### 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	13.9806
Shear X	-3.2901
Shear Z	0.4797
Moment X	1.7942
Moment Y (Twist)	0.6008
Moment Z	41.5395

### 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	8.7678
Shear X	-1.9628
Shear Z	0.3037
Moment X	1.1274
Moment Y (Twist)	0.3371
Moment Z	24.2031

## 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	-0.0376	2.7744	0.0000	-0.0000	0.0000	0.4004
ULS: 2. D + L	-0.0376	2.7744	0.0000	-0.0000	0.0000	0.4004
ULS: 3. D + (S or Lr or R)	-0.1531	9.4705	0.0000	-0.0001	0.0002	1.5990
ULS: 3. D + (S or Lr or R)	-0.0376	2.7744	0.0000	-0.0000	0.0000	0.4004
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1242	7.7965	0.0000	-0.0000	0.0001	1.2993
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0376	2.7744	0.0000	-0.0000	0.0000	0.4004
ULS: 5b. D + 0.7E	-0.0376	2.7744	0.0000	-0.0000	0.0000	0.4004

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1242	7.7965	0.0000	-0.0000	0.0001	1.2993
ULS: 8. 0.6D + 0.7E	-0.0226	1.6646	0.0000	-0.0000	0.0000	0.2402
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4211	7.0139	0.0000	-0.0000	0.0000	28.9844
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4211	7.0139	0.0000	-0.0000	0.0000	28.9844
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0167	-0.8714	0.0000	-0.0000	0.0000	-22.5379
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6304	-0.2219	0.0000	-0.0000	0.0000	-26.4055
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9118	10.9761	0.0000	-0.0000	0.0001	22.7374
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9118	10.9761	0.0000	-0.0000	0.0001	22.7374
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4165	5.0622	0.0000	-0.0000	0.0001	-15.9044
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1268	5.5493	0.0000	-0.0000	0.0001	-18.8050
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8252	5.9540	0.0000	-0.0000	0.0000	21.8384
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8252	5.9540	0.0000	-0.0000	0.0000	21.8384
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5032	0.0401	0.0000	-0.0000	0.0000	-16.8033
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2134	0.5271	0.0000	-0.0000	0.0000	-19.7040
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4061	5.9042	0.0000	-0.0000	0.0000	28.8242
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4061	5.9042	0.0000	-0.0000	0.0000	28.8242
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0318	-1.9811	0.0000	-0.0000	0.0000	-22.6980
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6454	-1.3317	0.0000	-0.0000	0.0000	-26.5656

#### 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	17.5610
Shear X	-4.0615
Shear Z	0.0000
Moment X	-0.0004
Moment Y (Twist)	0.0009
Moment Z	50.5637

#### 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	10.9761
Shear X	-2.4211
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0002
Moment Z	28.9844

#### 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	0.0188	2.3066	-0.0539	-0.2012	0.0343	-0.1547
ULS: 2. D + L	0.0188	2.3066	-0.0539	-0.2012	0.0343	-0.1547
ULS: 3. D + (S or Lr or R)	0.0765	7.5579	-0.2217	-0.8305	0.1423	-0.7025
ULS: 3. D + (S or Lr or R)	0.0188	2.3066	-0.0539	-0.2012	0.0343	-0.1547
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0621	6.2451	-0.1798	-0.6732	0.1153	-0.5655
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0188	2.3066	-0.0539	-0.2012	0.0343	-0.1547
ULS: 5b. D + 0.7E	0.0188	2.3066	-0.0539	-0.2012	0.0343	-0.1547
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0621	6.2451	-0.1798	-0.6732	0.1153	-0.5655
ULS: 8. 0.6D + 0.7E	0.0113	1.3840	-0.0323	-0.1207	0.0206	-0.0928
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9553	5.6702	-0.2191	-0.8071	0.3304	24.1413
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9553	5.6702	-0.2191	-0.8071	0.3304	24.1413
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7052	-0.5706	0.0816	0.2928	-0.2082	-19.6865
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4461	-0.1120	0.0800	0.2869	-0.2081	-23.6099
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4185	8.7678	-0.3037	-1.1276	0.3374	17.6564
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4185	8.7678	-0.3037	-1.1276	0.3374	17.6564
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3269	4.0872	-0.0782	-0.3027	-0.0665	-15.2144
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1326	4.4312	-0.0794	-0.3071	-0.0665	-18.1569

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4618	4.8293	-0.1778	-0.6557	0.2564	18.0673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4618	4.8293	-0.1778	-0.6557	0.2564	18.0673
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2836	0.1487	0.0477	0.1693	-0.1475	-14.8035
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0893	0.4927	0.0465	0.1649	-0.1475	-17.7461
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9628	4.7476	-0.1976	-0.7266	0.3167	24.2031
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9628	4.7476	-0.1976	-0.7266	0.3167	24.2031
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6977	-1.4932	0.1031	0.3732	-0.2219	-19.6246
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4386	-1.0346	0.1015	0.3674	-0.2218	-23.5480

### 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	13.9805
Shear X	-3.2901
Shear Z	-0.4797
Moment X	-1.7956
Moment Y (Twist)	0.6013
Moment Z	41.5410

### 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	8.7678
Shear X	-1.9628
Shear Z	-0.3037
Moment X	-1.1276
Moment Y (Twist)	0.3374
Moment Z	24.2031

## Project Details

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



User Name: sales@mtsolar.us  
 Project Name: UnivofMNMorris-JB-RevE  
 Unit System: imperial

## Design Input Information

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

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

**Section Dimensions**

ID	Name	d (in)	t <sub>w</sub> (in)				
3	2in Pipe Sch 120	2.38	0.25				
6	4in Pipe Sch 120	4.50	0.44				
8	6in Pipe Sch 80	6.63	0.43				

ID	Name	d (in)	b (in)	t <sub>w</sub> (in)	t <sub>b</sub> (in)	r (in)	
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23	

ID	Name	d (in)	t <sub>w</sub> (in)	b <sub>t</sub> (in)	b <sub>b</sub> (in)	t <sub>t</sub> (in)	t <sub>b</sub> (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	0.30

Section Properties								
ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	I <sub>yp</sub> (in <sup>4</sup> )	I <sub>zp</sub> (in <sup>4</sup> )	I <sub>w</sub> (in <sup>6</sup> )	S <sub>yp</sub> (in <sup>3</sup> )	S <sub>zp</sub> (in <sup>3</sup> )
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24

8	6in Pipe Sch 80	8.40	80.98	40.49	40.49	0.00	16.60	16.60
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties														
Member ID	Section ID	K <sub>z</sub> L (ft)	K <sub>y</sub> L (ft)	L <sub>b</sub> (ft)	C <sub>b</sub>	L	S	T	L	S	T	L	S	T
1	8	24.70	24.70	11.76	-	3	0	0	2	0	0	1		
2	6	1.30	1.30	2.00	-	3	0	0	2	0	0	1		
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.16,1.18,1.18,1.17,1.17	3	0	0	2	0	0	1		
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.76,1.67,1.67,1.67,1.67,1.68,1.68,1.62,1.71,1.67,1.67,1.66,2.26	3	0	0	2	0	0	1		
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	3	0	0	2	0	0	1		
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.17,1.18,1.18,1.18,1.18	3	0	0	2	0	0	1		
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	3	0	0	2	0	0	1		
8	20	1.33	1.33	2.05	1.55,1.55,1.55,1.55,1.55,1.55,1.53,1.53,1.45,2.08,1.52,1.52,1.51,1.27,1.54,1.54,1.57,1.60,1.53,1.53,1.48,2.10,1.52,1.52,1.51,1.00	3	0	0	2	0	0	1		
9	3	2.60	2.60	4.00	-	3	0	0	2	0	0	1		
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.91,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.56	3	0	0	2	0	0	1		
11	20	1.33	1.33	2.05	1.62,1.62,1.62,1.62,1.62,1.62,1.68,1.68,1.95,2.06,1.69,1.69,1.73,1.85,1.65,1.65,1.58,1.51,1.67,1.67,1.86,1.99,1.70,1.70,1.72,1.83	3	0	0	2	0	0	1		
12	6	4.20	4.20	2.00	-	3	0	0	2	0	0	1		
13	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.09,1.17,1.10,1.10,1.09,1.11,1.10,1.10,1.12,1.11,1.11,1.10,1.10,1.15,1.10,1.10,1.09,1.11	3	0	0	2	0	0	1		
14	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.09,1.20,1.11,1.11,1.10,2.76,1.11,1.11,1.11,1.12,1.11,1.11,1.10,1.23,1.11,1.11,1.10,1.73	3	0	0	2	0	0	1		
15	20	7.88	7.88	3.75	2.33,2.33	3	0	0	2	0	0	1		
16	20	7.88	7.88	3.75	2.33,2.33	3	0	0	2	0	0	1		
101	8	24.70	24.70	11.76	-	3	0	0	2	0	0	1		
102	6	1.30	1.30	2.00	-	3	0	0	2	0	0	1		
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	3	0	0	2	0	0	1		
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.93,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.59	3	0	0	2	0	0	1		
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3	0	0	2	0	0	1		
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	3	0	0	2	0	0	1		
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3	0	0	2	0	0	1		



## Member Design Capacity

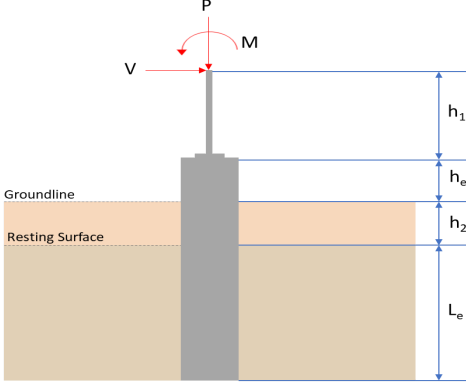
Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	378.22	104.11	62.23	62.23	113.47	113.47
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	229.64	27.16	27.16	75.30	75.30
13	159.30	116.35	33.01	6.46	56.26	44.91
14	159.30	116.35	33.31	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	378.22	104.11	62.23	62.23	113.47	113.47
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	142.47	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	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	31.17	6.46	56.26	44.91
114	159.30	116.35	30.87	6.46	56.26	44.91
115	159.30	48.27	14.35	6.46	56.26	44.91
116	159.30	48.27	15.14	6.46	56.26	44.91
201	378.22	104.11	62.23	62.23	113.47	113.47
202	251.01	229.64	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	55.15	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	55.15	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	33.01	6.46	56.26	44.91
214	159.30	116.35	33.31	6.46	56.26	44.91
215	159.30	48.27	14.74	6.46	56.26	44.91
216	159.30	48.27	14.74	6.46	56.26	44.91

## 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	0.134	0.667	0.062	0.029	0.004	0.746	#13	0.675	Not Required	Pass
2	0.004	0.337	0.115	0.078	0.021	0.428	#21	0.036	Not Required	Pass
3	0.007	0.518	0.042	0.051	0.010	0.535	#21	0.046	Not Required	Pass
4	0.006	0.514	0.134	0.051	0.030	0.617	#21	0.082	Not Required	Pass
5	0.007	0.321	0.122	0.051	0.033	0.354	#21	0.076	Not Required	Pass
6	0.011	0.654	0.089	0.066	0.017	0.748	#21	0.046	Not Required	Pass
7	0.011	0.406	0.231	0.064	0.059	0.463	#21	0.076	Not Required	Pass
8	0.003	0.090	0.283	0.041	0.024	0.286	#24	0.102	Not Required	Pass
9	0.018	0.059	0.079	0.002	0.004	0.140	#21	0.206	Not Required	Pass
10	0.012	0.624	0.215	0.062	0.045	0.739	#21	0.082	Not Required	Pass
11	0.005	0.086	0.294	0.043	0.024	0.300	#24	0.102	Not Required	Pass
12	0.003	0.478	0.137	0.103	0.024	0.586	#21	0.174	Not Required	Pass
13	0.007	0.179	0.620	0.054	0.029	0.736	#21	0.306	Not Required	Pass
14	0.008	0.172	0.606	0.051	0.029	0.698	#24	0.204	Not Required	Pass
15	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
16	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
101	0.169	0.812	0.000	0.036	0.000	0.878	#13	0.675	Not Required	Pass
102	0.006	0.518	0.160	0.114	0.027	0.654	#21	0.036	Not Required	Pass
103	0.011	0.729	0.058	0.072	0.002	0.786	#21	0.046	Not Required	Pass
104	0.011	0.749	0.234	0.075	0.049	0.898	#21	0.082	Not Required	Pass
105	0.011	0.453	0.246	0.072	0.065	0.520	#21	0.076	Not Required	Pass
106	0.011	0.729	0.058	0.072	0.002	0.786	#21	0.046	Not Required	Pass
107	0.011	0.453	0.246	0.072	0.065	0.520	#21	0.076	Not Required	Pass
108	0.003	0.067	0.313	0.049	0.024	0.381	#21	0.102	Not Required	Pass
109	0.029	0.060	0.051	0.001	0.000	0.124	#21	0.206	Not Required	Pass
110	0.011	0.749	0.234	0.075	0.049	0.898	#21	0.082	Not Required	Pass
111	0.005	0.070	0.322	0.046	0.024	0.356	#21	0.102	Not Required	Pass
112	0.006	0.518	0.160	0.114	0.027	0.654	#21	0.036	Not Required	Pass
113	0.007	0.232	0.653	0.057	0.030	0.864	#21	0.306	Not Required	Pass
114	0.010	0.296	0.644	0.059	0.030	0.914	#21	0.306	Not Required	Pass
115	0.016	0.556	0.336	0.046	0.024	0.910	#21	0.644	Not Required	Pass
116	0.005	0.513	0.332	0.049	0.024	0.845	#21	0.644	Not Required	Pass
201	0.134	0.668	0.062	0.029	0.004	0.746	#13	0.675	Not Required	Pass
202	0.003	0.478	0.137	0.103	0.024	0.586	#21	0.174	Not Required	Pass
203	0.011	0.654	0.089	0.066	0.017	0.748	#21	0.046	Not Required	Pass
204	0.012	0.624	0.215	0.062	0.045	0.739	#21	0.082	Not Required	Pass
205	0.011	0.406	0.230	0.064	0.059	0.463	#21	0.076	Not Required	Pass
206	0.007	0.518	0.042	0.051	0.010	0.535	#21	0.046	Not Required	Pass
207	0.007	0.321	0.122	0.051	0.033	0.354	#21	0.076	Not Required	Pass
208	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
209	0.018	0.059	0.079	0.002	0.004	0.140	#21	0.206	Not Required	Pass
210	0.006	0.514	0.134	0.051	0.030	0.617	#21	0.082	Not Required	Pass
211	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
212	0.004	0.337	0.115	0.078	0.021	0.428	#21	0.036	Not Required	Pass
213	0.007	0.179	0.619	0.054	0.029	0.735	#21	0.204	Not Required	Pass
214	0.008	0.172	0.606	0.051	0.029	0.699	#24	0.306	Not Required	Pass
215	0.016	0.576	0.335	0.043	0.024	0.914	#21	0.644	Not Required	Pass
216	0.005	0.539	0.327	0.041	0.024	0.866	#21	0.644	Not Required	Pass

## Definitions

$\Phi_t$	Safety factor for tensile
$\Phi_c$	Safety factor for compression
$\Phi_b$	Safety factor for flexure
$\Phi_v$	Safety factor for shear
E	Modulus of elasticity
$F_y$	Specified minimum yield stress
$F_u$	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
$I_{yp}$	Moment of inertia about the Y axes
$I_{zp}$	Moment of inertia about the Z axes
$I_w$	Warping constant
$S_{yp}$	Plastic section modulus about the Y axis
$S_{zp}$	Plastic section modulus about the Z axis
KL	Effective length
$C_b$	Buckling modification factor (from all load combinations)
$L_b$	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
$P_n$	Nominal axial strength (tension/compression)
$M_n$	Nominal flexural strength (about Z/Y axis)
$V_n$	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
$M_z$	Design ratio in case of bending about Z axis
$M_y$	Design ratio in case of bending about Y axis
$V_y$	Design ratio in case of shear along Y axis
$V_z$	Design ratio in case of shear along Z axis
$(P, M_z, M_y)$	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
$\delta$	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.25</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.768</td> <td>13.981</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-1.963</td> <td>-3.290</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.304</td> <td>0.480</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>1.127</td> <td>1.794</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>24.203</td> <td>41.540</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.768	13.981	$V_x$ (kip)	-1.963	-3.290	$V_z$ (kip)	0.304	0.480	$M_x$ (kipft)	1.127	1.794	$M_z$ (kipft)	24.203	41.540	
Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)																									
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																									
Load Component	ASD	LRFD																										
$P$ (kip)	8.768	13.981																										
$V_x$ (kip)	-1.963	-3.290																										
$V_z$ (kip)	0.304	0.480																										
$M_x$ (kipft)	1.127	1.794																										
$M_z$ (kipft)	24.203	41.540																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.963 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.31258 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(24.203 \text{ kipft}) + ((-1.963 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.854 \text{ kipft/ft}$$

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:

$L_{e,x} = 5.8368 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.304 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.048408 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.127 \text{ kipft}) + ((0.304 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.17946 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.8258 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.8368 \text{ ft}), (2.8258 \text{ ft})]$$

$$L_{e,req} = 5.837 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.837 \text{ ft})}{(6.25 \text{ ft})}$$

$$\text{Ratio} = 0.93392$$

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

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

$$q = \frac{(8.768 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.548 \text{ kip/ft}^2$$

$$q = 0.040 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$Ratio = \frac{(0.548 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.274$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5625$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.31258 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 3.854 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (3.854 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (3.854 \text{ kipft/ft})) + (4 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2982 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (3.854 \text{ kipft/ft})) + (3 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 [(3 \times (3.854 \text{ kipft/ft})) + (2 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.229 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 [(2 \times (3.854 \text{ kipft/ft})) + ((-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.88387 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2982 \text{ ft})}{2}$$

$$p_a = 0.32237 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.229 \text{ kip/ft}^2)}{(0.32237 \text{ kip/ft}^2)}$$

$$Ratio = 0.71038$$

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

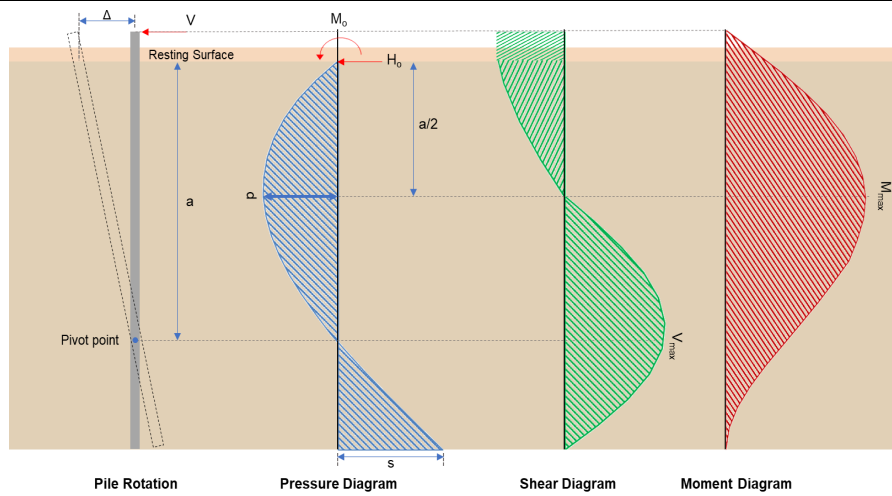
Status: **PASS**  
Ratio: **0.710**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.25 \text{ ft})$ $p_s = 0.9375 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.88387 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.94279$	<p>Status: <b>PASS</b> Ratio: <b>0.940</b></p>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = 0.048408 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.17946 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.17946 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (0.048408 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (0.17946 \text{ kipft/ft})) + (4 \times (0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))}$ $a = 4.4423 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.17946 \text{ kipft/ft})) + (3 \times (0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 \times [(3 \times (0.17946 \text{ kipft/ft})) + (2 \times (0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$ $p = 0.044365 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.17946 \text{ kipft/ft})) + ((0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$ $s = 0.1016 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.4423 \text{ ft})}{2}$ $p_a = 0.33317 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.044365 \text{ kip/ft}^2)}{(0.33317 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.13316$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.25 \text{ ft})$ $p_s = 0.9375 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	<p>Status: <b>PASS</b> Ratio: <b>0.130</b></p>

$$Ratio = \frac{(0.1016 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$$

$$Ratio = 0.10837$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.29 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.52389 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(41.54 \text{ kipft}) + ((-3.29 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6146 \text{ kipft/ft}$$

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

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

$$E = \frac{(6.6146 \text{ kipft/ft})}{(-0.52389 \text{ kip/ft})}$$

$$E = 12.626 \text{ ft}$$

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

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

$$a = \frac{(4 \times (6.6146 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.52389 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (6.6146 \text{ kipft/ft})) + (4 \times (-0.52389 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2959 \text{ ft}$$

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

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

$$V_{max} = ((-0.52389 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.2959 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.2959 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.8746 \text{ kip}$$

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

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

$$M_{max} = ((-0.52389 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[ \left( \frac{(12.626 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 26.542 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.48 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.076433 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.794 \text{ kipft}) + ((0.48 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.28567 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.28567 \text{ kipft/ft})}{(0.076433 \text{ kip/ft})}$$

$$E = 3.7375 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.28567 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (0.076433 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (0.28567 \text{ kipft/ft})) + (4 \times (0.076433 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.4412 \text{ ft}$$

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

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

$$V_{max} = ((0.076433 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7375 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.4412 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.7375 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.4412 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.52668 \text{ kip}$$

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

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

$$M_{max} = ((0.076433 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[ \left( \frac{(3.7375 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.4412 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.7375 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.4412 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7375 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.4412 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.475 \text{ kipft}$$

### 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,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.981 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.132 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.132 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

$s_{rebar}$  - Minimum spacing of reinforcement,

$$s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$$

$$s_{rebar} = \text{Max} [1.5, (1.5 \times (0.625 \text{ in}))]$$

$$s_{rebar} = 1.5 \text{ in}$$

#### Ties:

25.7.2.2

Since longitudinal reinforcement is  $\leq$  No. 10: Use #3(0.375 in)

25.7.2.1

$s_{ties}$  - Maximum spacing of ties,

$$s_{ties} = \text{Min} [(16 d_{bar}), (48 d_{ties}), \text{Min} (D, b)]$$

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min} ((48 \text{ in}), (48 \text{ in}))]$$

$$s_{ties} = 10 \text{ in}$$

#### Summary:

Main reinforcement: **14 - #5 (0.625 in)**

Ties: #3(0.375 in) - 10 in

**Axial Compression Strength (ACI 318-19, LRFD)**

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

$$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$$

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 2675.2 \text{ kip}$$

Ratio - Capacity

$$\text{Ratio} = \frac{P}{\phi P_N}$$

$$\text{Ratio} = \frac{(13.981 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0052262$$

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

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

**Parameters:**

22.5.2.2

$b_w = 48 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (48 \text{ in})$$

$$d = 38.4 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$$

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

$$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$$

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 13.981 \text{ kip} \rightarrow 13981 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13981 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.35 \text{ kip}$$

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

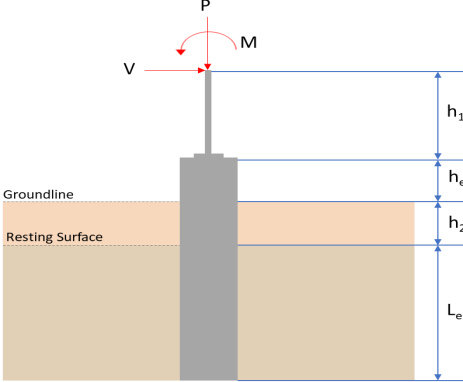
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.35 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.35 \text{ kip}$$

<p>22.5.1.2</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_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.35 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.31 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 8.8746 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(8.8746 \text{ kip})}{(111.31 \text{ kip})}$ $\text{Ratio} = 0.07973$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.52668 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.52668 \text{ kip})}{(111.31 \text{ kip})}$ $\text{Ratio} = 0.0047317$	<p>Status: <b>PASS</b> Ratio: <b>0.080</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 26.542 \text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(26.542 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.10634$	<p>Status: <b>PASS</b>  Ratio: <b>0.110</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 1.475 \text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.475 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.0059095$	<p>Status: <b>PASS</b>  Ratio: <b>0.010</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.25</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.768</td> <td>13.981</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-1.963</td> <td>-3.290</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.304</td> <td>-0.480</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-1.128</td> <td>-1.796</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>24.203</td> <td>41.541</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.768	13.981	$V_x$ (kip)	-1.963	-3.290	$V_z$ (kip)	-0.304	-0.480	$M_x$ (kipft)	-1.128	-1.796	$M_z$ (kipft)	24.203	41.541	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.963 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.31258 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(24.203 \text{ kipft}) + ((-1.963 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.854 \text{ kipft/ft}$$

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:

$L_{e,x} = 5.8368 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.304 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.048408 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.128 \text{ kipft}) + ((-0.304 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.17962 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.037 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.8368 \text{ ft}), (2.037 \text{ ft})]$$

$$L_{e,req} = 5.837 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.837 \text{ ft})}{(6.25 \text{ ft})}$$

$$\text{Ratio} = 0.93392$$

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

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

$$q = \frac{(8.768 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.548 \text{ kip/ft}^2$$

$$q = 0.040 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$Ratio = \frac{(0.548 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.274$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(6.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5625$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.31258 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 3.854 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (3.854 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (3.854 \text{ kipft/ft})) + (4 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2982 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (3.854 \text{ kipft/ft})) + (3 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 [(3 \times (3.854 \text{ kipft/ft})) + (2 \times (-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.229 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 [(2 \times (3.854 \text{ kipft/ft})) + ((-0.31258 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.88387 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2982 \text{ ft})}{2}$$

$$p_a = 0.32237 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.229 \text{ kip/ft}^2)}{(0.32237 \text{ kip/ft}^2)}$$

$$Ratio = 0.71038$$

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

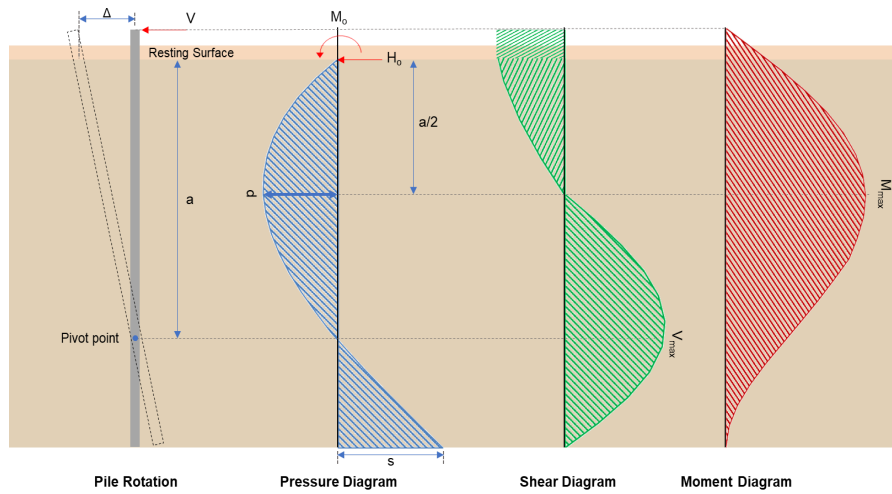
Status: **PASS**  
Ratio: **0.710**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.25 \text{ ft})$ $p_s = 0.9375 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.88387 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.94279$	Status: <b>PASS</b> Ratio: <b>0.940</b>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = -0.048408 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.17962 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.17962 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.048408 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (0.17962 \text{ kipft/ft})) + (4 \times (-0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))}$ $a = 4.4422 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 [(4 \times (0.17962 \text{ kipft/ft})) + (3 \times (-0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 [(3 \times (0.17962 \text{ kipft/ft})) + (2 \times (-0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$ $p = -0.010372 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 [(2 \times (0.17962 \text{ kipft/ft})) + ((-0.048408 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$ $s = 0.0087073 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.4422 \text{ ft})}{2}$ $p_a = 0.33316 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.010372 \text{ kip/ft}^2)}{(0.33316 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.031133$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.25 \text{ ft})$ $p_s = 0.9375 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: <b>PASS</b> Ratio: <b>-0.030</b>

$$Ratio = \frac{(0.0087073 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$$

$$Ratio = 0.0092877$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.29 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.52389 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(41.541 \text{ kipft}) + ((-3.29 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.6148 \text{ kipft/ft}$$

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

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

$$E = \frac{(6.6148 \text{ kipft/ft})}{(-0.52389 \text{ kip/ft})}$$

$$E = 12.626 \text{ ft}$$

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

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

$$a = \frac{(4 \times (6.6148 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.52389 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (6.6148 \text{ kipft/ft})) + (4 \times (-0.52389 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2959 \text{ ft}$$

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

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

$$V_{max} = ((-0.52389 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.2959 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.2959 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.8748 \text{ kip}$$

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

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

$$M_{max} = ((-0.52389 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[ \left( \frac{(12.626 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.626 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.2959 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 26.542 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.48 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.076433 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.796 \text{ kipft}) + ((-0.48 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.28599 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.28599 \text{ kipft/ft})}{(-0.076433 \text{ kip/ft})}$$

$$E = 3.7417 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.28599 \text{ kipft/ft}) \times (6.25 \text{ ft})) + (3 \times (-0.076433 \text{ kip/ft}) \times (6.25 \text{ ft})^2)}{(6 \times (0.28599 \text{ kipft/ft})) + (4 \times (-0.076433 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.4411 \text{ ft}$$

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

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

$$V_{max} = ((-0.076433 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.7417 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.4411 \text{ ft})}{(6.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.7417 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.4411 \text{ ft})}{(6.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.52703 \text{ kip}$$

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

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

$$M_{max} = ((-0.076433 \text{ kip/ft}) \times (48 \text{ in}) \times (6.25 \text{ ft})) \times \left[ \left( \frac{(3.7417 \text{ ft})}{(6.25 \text{ ft})} + \frac{(4.4411 \text{ ft})}{2 \times (6.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.7417 \text{ ft})}{(6.25 \text{ ft})} + 3 \right) \times \left( \frac{(4.4411 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.7417 \text{ ft})}{(6.25 \text{ ft})} + 2 \right) \times \left( \frac{(4.4411 \text{ ft})}{2 \times (6.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.4761 \text{ kipft}$$

### 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,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.981 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.132 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.132 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

$s_{rebar}$  - Minimum spacing of reinforcement,

$$s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$$

$$s_{rebar} = \text{Max} [1.5, (1.5 \times (0.625 \text{ in}))]$$

$$s_{rebar} = 1.5 \text{ in}$$

#### Ties:

25.7.2.2

Since longitudinal reinforcement is  $\leq$  No. 10: Use #3(0.375 in)

25.7.2.1

$s_{ties}$  - Maximum spacing of ties,

$$s_{ties} = \text{Min} [(16 d_{bar}), (48 d_{ties}), \text{Min} (D, b)]$$

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min} ((48 \text{ in}), (48 \text{ in}))]$$

$$s_{ties} = 10 \text{ in}$$

#### Summary:

Main reinforcement: **14 - #5 (0.625 in)**

Ties: #3(0.375 in) - 10 in

**Axial Compression Strength (ACI 318-19, LRFD)**

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

$$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$$

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 2675.2 \text{ kip}$$

Ratio - Capacity

$$\text{Ratio} = \frac{P}{\phi P_N}$$

$$\text{Ratio} = \frac{(13.981 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0052262$$

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

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

**Parameters:**

22.5.2.2

$b_w = 48 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (48 \text{ in})$$

$$d = 38.4 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$$

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

$$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$$

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 13.981 \text{ kip} \rightarrow 13981 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13981 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.35 \text{ kip}$$

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

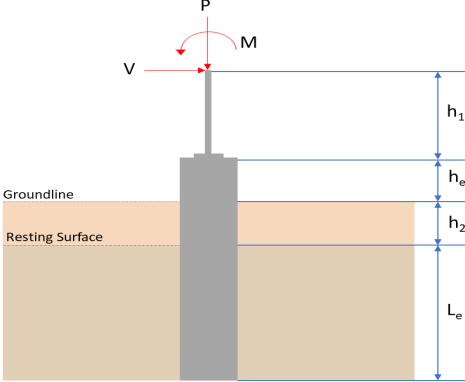
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.35 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.35 \text{ kip}$$

<p>22.5.1.2</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_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.35 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.31 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 8.8748 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(8.8748 \text{ kip})}{(111.31 \text{ kip})}$ $\text{Ratio} = 0.079732$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.52703 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.52703 \text{ kip})}{(111.31 \text{ kip})}$ $\text{Ratio} = 0.0047349$	<p>Status: <b>PASS</b> Ratio: <b>0.080</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 26.542 \text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(26.542 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.10634$	<p>Status: <b>PASS</b>  Ratio: <b>0.110</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 1.4761 \text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.4761 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.0059139$	<p>Status: <b>PASS</b>  Ratio: <b>0.010</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.5</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>10.976</td> <td>17.561</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.421</td> <td>-4.061</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>28.984</td> <td>50.564</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	10.976	17.561	$V_x$ (kip)	-2.421	-4.061	$V_z$ (kip)	0.000	0.000	$M_x$ (kipft)	0.000	0.000	$M_z$ (kipft)	28.984	50.564	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.421 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.38551 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(28.984 \text{ kipft}) + ((-2.421 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6153 \text{ kipft/ft}$$

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:

$$L_{e,x} = 6.1085 \text{ ft} - \text{Required depth in x-direction,}$$

**Considering z-direction:**

$$L_{e,z} = 0 \text{ ft} - \text{Required depth in z-direction,}$$

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.1085 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 6.108 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.108 \text{ ft})}{(6.5 \text{ ft})}$$

$$\text{Ratio} = 0.9397$$

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

### End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.976 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.686 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

**Ratio** - Capacity

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

$$\text{Ratio} = \frac{(0.686 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.343$$

Status: **PASS**  
Ratio: **0.340**

Czerniak

### Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.625$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.38551$  kip/ft - Lateral force per length of pile,

$M_o = 4.6153$  kipft/ft - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.6153 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.38551 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (4.6153 \text{ kipft/ft})) + (4 \times (-0.38551 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4773 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.6153 \text{ kipft/ft})) + (3 \times (-0.38551 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (4.6153 \text{ kipft/ft})) + (2 \times (-0.38551 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.24065 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.6153 \text{ kipft/ft})) + ((-0.38551 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.955 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.4773 \text{ ft})}{2}$$

$$p_a = 0.3358 \text{ kip/ft}^2$$

*Ratio* - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.24065 \text{ kip/ft}^2)}{(0.3358 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71667$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

*Ratio* - Lateral soil capacity

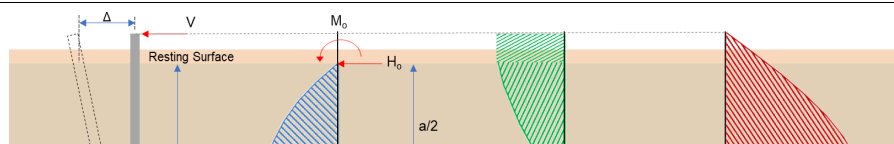
$$\text{Ratio} = \frac{s}{p_s}$$

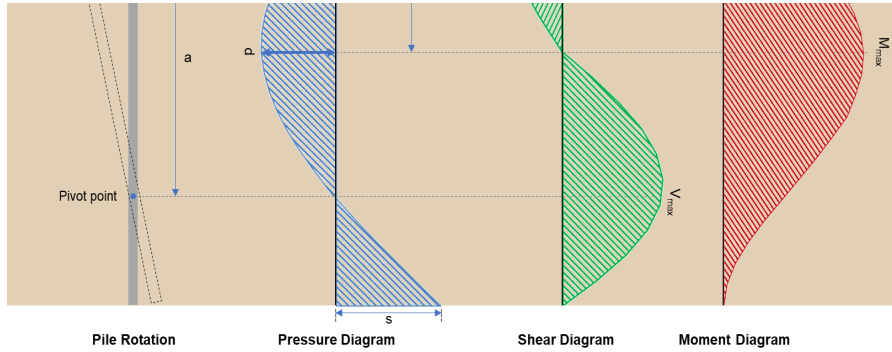
$$\text{Ratio} = \frac{(0.955 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.97948$$

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

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





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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-4.061 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.64666 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(50.564 \text{ kipft}) + ((-4.061 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.0516 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.0516 \text{ kipft/ft})}{(-0.64666 \text{ kip/ft})}$$

$$E = 12.451 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.0516 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.64666 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (8.0516 \text{ kipft/ft})) + (4 \times (-0.64666 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4732 \text{ ft}$$

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

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

$$V_{max} = ((-0.64666 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.451 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left( \frac{(4.4732 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.451 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left( \frac{(4.4732 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.475 \text{ kip}$$

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

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

$$M_{max} = ((-0.64666 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[ \left( \frac{(12.451 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4732 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.451 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left( \frac{(4.4732 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.451 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left( \frac{(4.4732 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 32.514 \text{ kipft}$$

### 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,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(17.561 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.013 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.013 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

$s_{rebar}$  - Minimum spacing of reinforcement,

$$s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$$

$$s_{rebar} = \text{Max} [1.5, (1.5 \times (0.625 \text{ in}))]$$

$$s_{rebar} = 1.5 \text{ in}$$

#### Ties:

25.7.2.2 Since longitudinal reinforcement is  $\leq$  No. 10: Use #3(0.375 in)

25.7.2.1

$s_{ties}$  - Maximum spacing of ties,

$$s_{ties} = \text{Min} [(16 d_{bar}), (48 d_{ties}), \text{Min} (D, b)]$$

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min} ((48 \text{ in}), (48 \text{ in}))]$$

$$s_{ties} = 10 \text{ in}$$

#### Summary:

Main reinforcement: **14 - #5 (0.625 in)**

**Axial Compression Strength (ACI 318-19, LRFD)**22.4.2.2  $\phi P_N$  - Allowable axial compressive strength

$$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}] + (f_{yk} A_{st})]$$

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 2675.2 \text{ kip}$$

Ratio - Capacity

$$\text{Ratio} = \frac{P}{\phi P_N}$$

$$\text{Ratio} = \frac{(17.561 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0065644$$

Status: **PASS**  
Ratio: **0.010****Shear Strength (ACI 318-19, LRFD)****Parameters:** $b_w = 48 \text{ in}$  - Effective width,22.5.2.2  $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (48 \text{ in})$$

$$d = 38.4 \text{ in}$$

22.5.5.1.3  $\lambda_s$  - size effect modification factor

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$$

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,22.5.5.1.1  $V_{c,max}$  - Max shear strength of concrete

$$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$$

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 17.561 \text{ kip} \rightarrow 17561 \text{ lbf}$ ,22.5.5.1.1(a)  $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17561 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.83 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.83 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.83 \text{ kip}$$

<p>22.5.1.2</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_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.83 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.62 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.475 \text{ kip}</math> - Maximum shear force in the x-direction,  <b>Ratio</b> - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.475 \text{ kip})}{(111.62 \text{ kip})}$ $\text{Ratio} = 0.093844$	<p>Status: <b>PASS</b>  Ratio: <b>0.090</b></p>
<p>14.5.2.1b</p>	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:</p> <p><math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$	

$$\phi M_{n,2} = \phi M_{n,1}$$

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

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

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:**

$M_{max} = 32.514 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(32.514 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.13027$$

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