

# Your Project Calculations



Project Name: MTSOLAR\_A83CF08J39IG

S3D Model Link:

[https://platform.skyciv.com/structural?preload\\_name=MTSOLAR\\_A83CF08J39IG&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/2\\_2024](https://platform.skyciv.com/structural?preload_name=MTSOLAR_A83CF08J39IG&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/2_2024)

Public Model Link:

[https://platform.skyciv.com/structural-viewer?project\\_id=gTjvls3OOk4IAT3XIRPpi163UxEvOR7taXgNymFbarNsamdLaBRUQaZiviPEZ7i](https://platform.skyciv.com/structural-viewer?project_id=gTjvls3OOk4IAT3XIRPpi163UxEvOR7taXgNymFbarNsamdLaBRUQaZiviPEZ7i)

## Array Specification

Product:	Beam
Unique ID:	4P-19.75-8TOP-XD-12-L-4Hx11W-AG8F
Duty Classification:	XD
Module Width:	42.00 in
Module Length:	76.00in
Number of Rows:	4
Number of Columns:	11
Total Number of Modules:	44
Desired Tilt Angle:	35
Front Edge Clearance:	4
Total Array Height at Tilt:	12.08 ft
Total Frame Length:	68.75 ft
Frame Weight:	3661 lbs
Array Dimensions N/S:	14.17 ft
Array Dimensions E/W:	70.58 ft
Rail Length:	170.00 in
Rail Spacing:	3.17 ft
Rail Check:	Not Checked

## Support Specifications

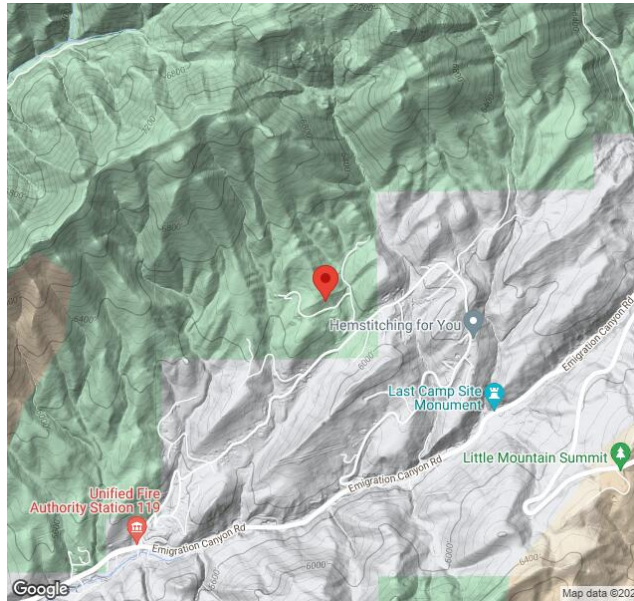
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	8.06 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

## Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 7.75 ft Pile 2: 8.25 ft Pile 3: 8.25 ft Pile 4: 7.75 ft
Foundation Volume:	8.378 y <sup>3</sup>
Foundation Result:	PASSED
Mount Twist:	1.473462 kip

## Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	5811 Twin Creek Rd, Salt Lake City, UT 84108, USA
Wind Speed:	105 mph
Snow Load:	80 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.030790 ksf



### Design Disclaimer

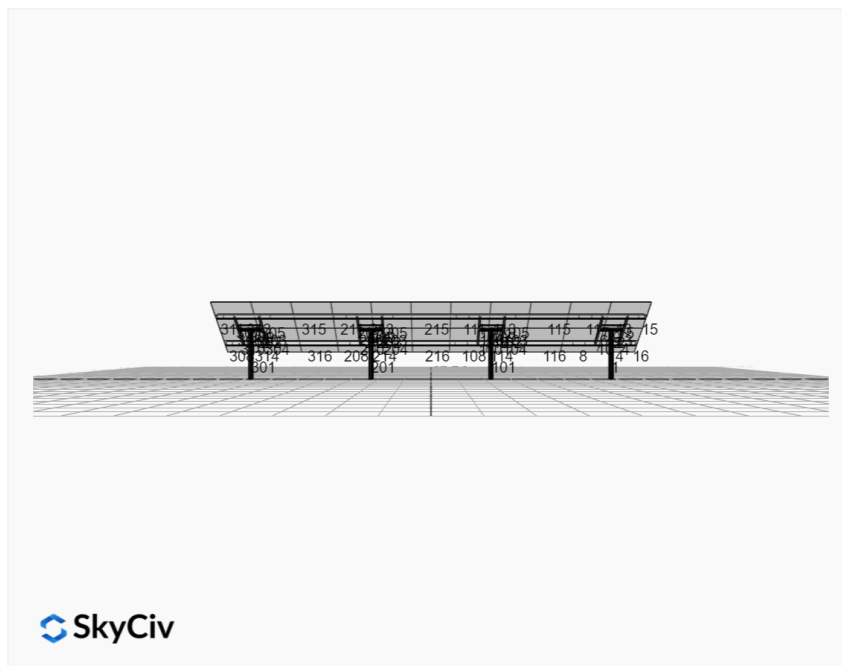
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

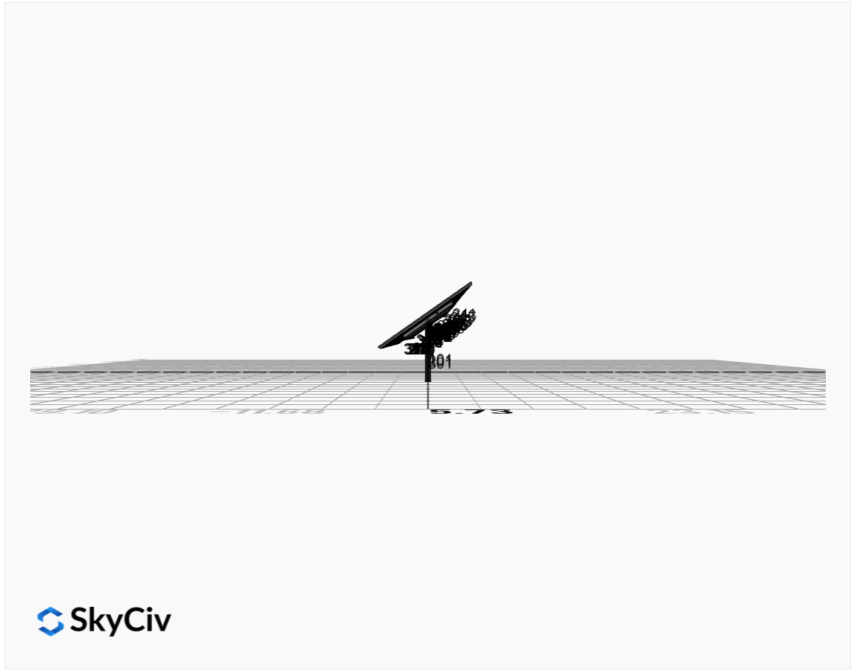
### AutoDesigner Input

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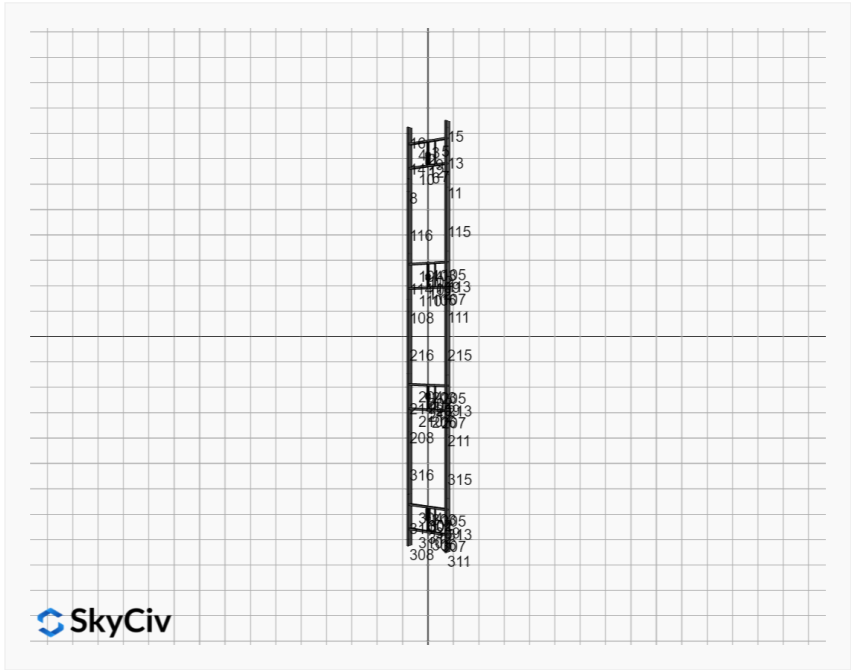
### Design Notes:

- 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
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)
- Foundation Design and Sizing is approximate only

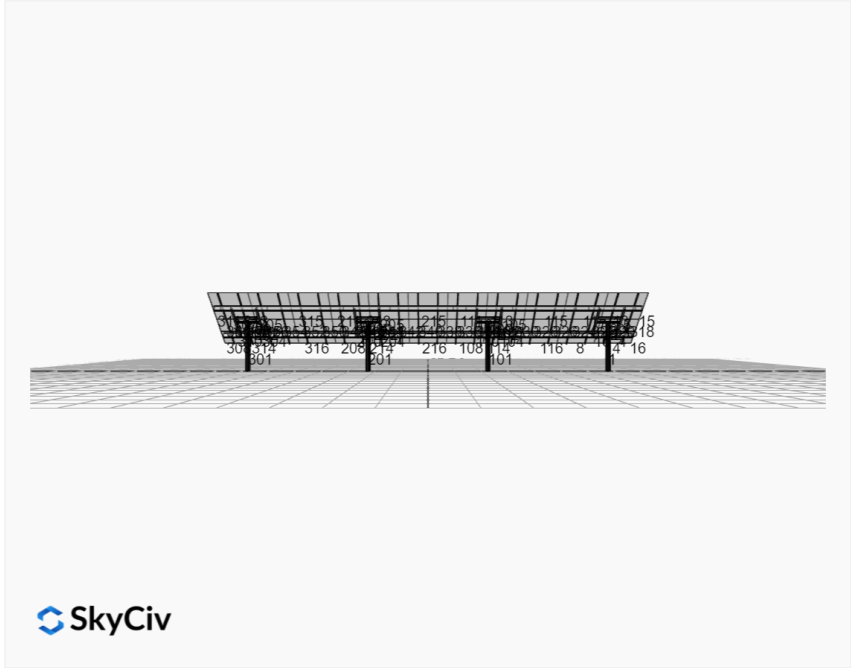
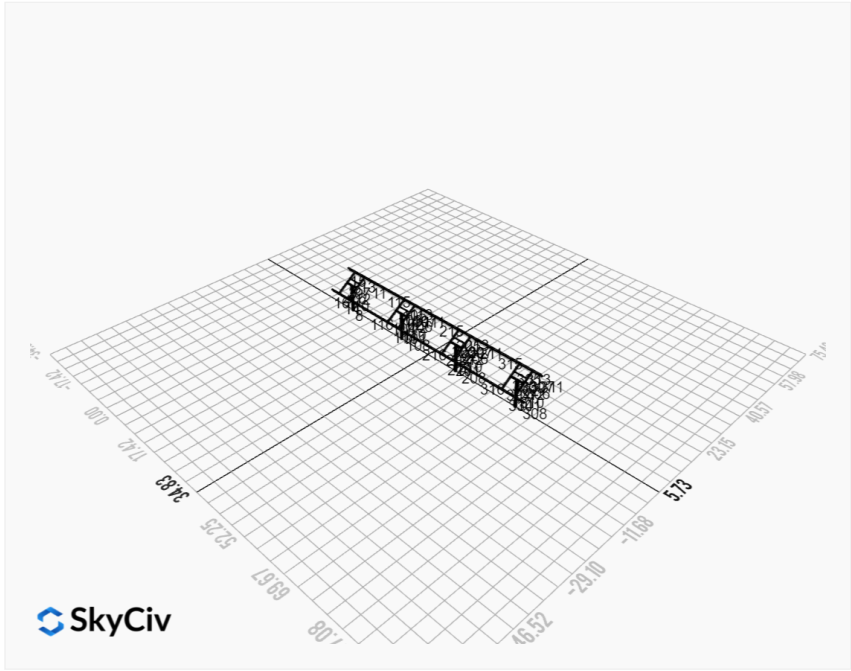




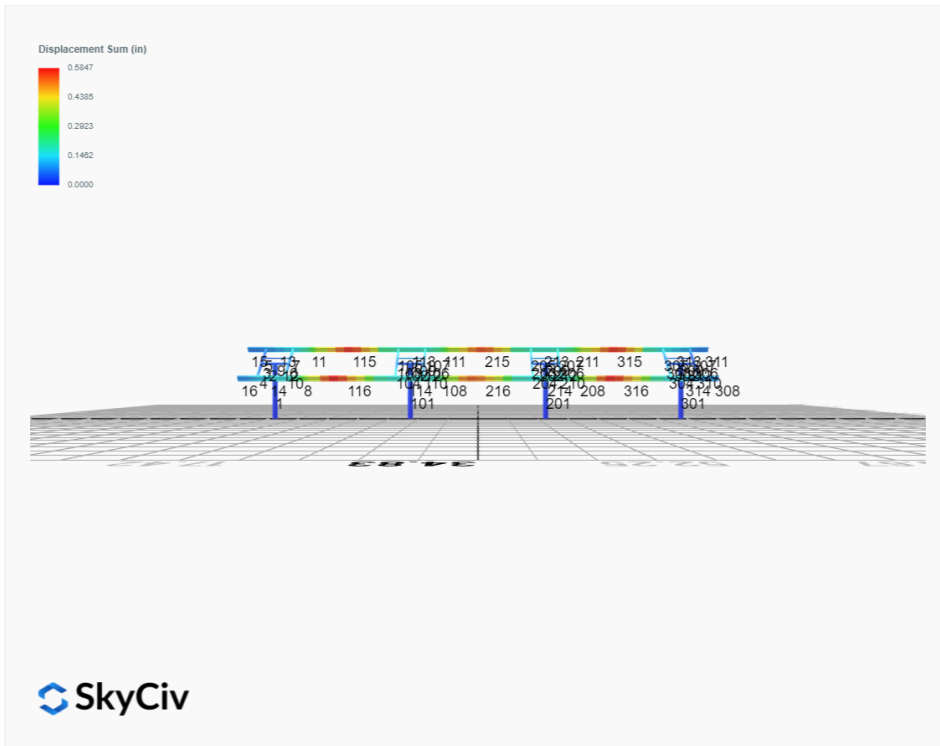
 SkyCiv



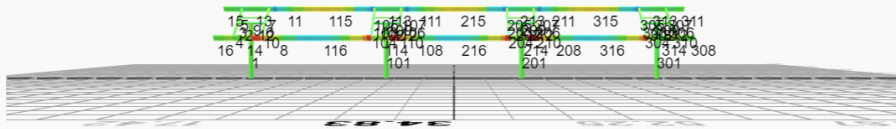
 SkyCiv



# FEM Results (Envelope Worst Case for each member)

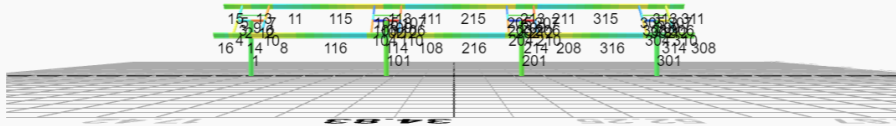


Top Bending Stress Y (ksi)

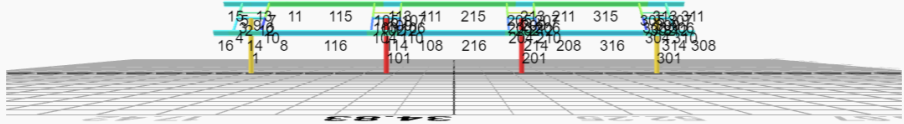
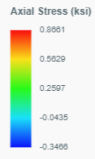


 SkyCiv

Shear Stress Y (ksi)



 SkyCiv



## 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	0.0369	1.7889	0.1028	0.1964	-0.0555	-0.2540
ULS: 2. D + L	0.0369	1.7889	0.1028	0.1964	-0.0555	-0.2540
ULS: 3. D + (S or Lr or R)	0.1809	6.7970	0.5054	0.9699	-0.2736	-1.3290
ULS: 3. D + (S or Lr or R)	0.0369	1.7889	0.1028	0.1964	-0.0555	-0.2540
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1449	5.5449	0.4047	0.7765	-0.2191	-1.0603
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0369	1.7889	0.1028	0.1964	-0.0555	-0.2540
ULS: 5b. D + 0.7E	0.0369	1.7889	0.1028	0.1964	-0.0555	-0.2540
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1449	5.5449	0.4047	0.7765	-0.2191	-1.0603
ULS: 8. 0.6D + 0.7E	0.0222	1.0733	0.0617	0.1178	-0.0333	-0.1524
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.0305	4.7069	0.4037	0.7130	-0.8308	16.9737
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.0305	4.7069	0.4037	0.7130	-0.8308	16.9737
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7799	-0.6719	-0.1477	-0.2338	0.5909	-14.3948
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5100	-0.2748	-0.1310	-0.2039	0.5567	-18.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4057	7.7335	0.6304	1.1639	-0.8006	11.8605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4057	7.7335	0.6304	1.1639	-0.8006	11.8605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4521	3.6993	0.2168	0.4539	0.2657	-11.6659
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2497	3.9972	0.2294	0.4763	0.2401	-14.5608
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5136	3.9774	0.3285	0.5838	-0.6370	12.6667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5136	3.9774	0.3285	0.5838	-0.6370	12.6667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3442	-0.0567	-0.0851	-0.1262	0.4293	-10.8596
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1417	0.2411	-0.0725	-0.1038	0.4036	-13.7545
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0453	3.9913	0.3626	0.6344	-0.8086	17.0753
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0453	3.9913	0.3626	0.6344	-0.8086	17.0753
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7652	-1.3875	-0.1888	-0.3124	0.6131	-14.2932
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4952	-0.9904	-0.1721	-0.2825	0.5789	-18.1531

### Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.5917
Shear X	-3.4458
Shear Z	1.0253
Moment X	1.9251
Moment Y (Twist)	1.4724
Moment Z	31.1139

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.7335
Shear X	-2.0453
Shear Z	0.6304
Moment X	1.1639
Moment Y (Twist)	0.8308
Moment Z	18.2547

## 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	-0.0369	2.3713	-0.0086	-0.0170	0.0211	0.3102
ULS: 2. D + L	-0.0369	2.3713	-0.0086	-0.0170	0.0211	0.3102
ULS: 3. D + (S or Lr or R)	-0.1809	9.6456	-0.0418	-0.0833	0.1031	1.4666
ULS: 3. D + (S or Lr or R)	-0.0369	2.3713	-0.0086	-0.0170	0.0211	0.3102
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1449	7.8270	-0.0335	-0.0668	0.0826	1.1775
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0369	2.3713	-0.0086	-0.0170	0.0211	0.3102
ULS: 5b. D + 0.7E	-0.0369	2.3713	-0.0086	-0.0170	0.0211	0.3102

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1449	7.8270	-0.0335	-0.0668	0.0826	1.1775
ULS: 8. 0.6D + 0.7E	-0.0222	1.4228	-0.0051	-0.0102	0.0126	0.1861
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0650	6.7305	-0.0176	-0.0391	0.0175	25.0818
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.0650	6.7305	-0.0176	-0.0391	0.0175	25.0818
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5194	-1.3080	0.0004	0.0038	0.0199	-19.9441
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0728	-0.6817	-0.0148	-0.0229	0.0645	-24.8233
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4159	11.0964	-0.0403	-0.0833	0.0800	19.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4159	11.0964	-0.0403	-0.0833	0.0800	19.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7724	5.0676	-0.0268	-0.0512	0.0817	-14.0132
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4374	5.5372	-0.0382	-0.0711	0.1152	-17.6726
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3080	5.6407	-0.0154	-0.0336	0.0184	18.8889
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3080	5.6407	-0.0154	-0.0336	0.0184	18.8889
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8803	-0.3881	-0.0018	-0.0014	0.0202	-14.8805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5454	0.0815	-0.0133	-0.0214	0.0537	-18.5399
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0502	5.7819	-0.0142	-0.0323	0.0091	24.9577
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.0502	5.7819	-0.0142	-0.0323	0.0091	24.9577
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5342	-2.2565	0.0039	0.0106	0.0115	-20.0682
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0876	-1.6303	-0.0114	-0.0160	0.0561	-24.9474

#### 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	18.1166
Shear X	-5.1624
Shear Z	-0.0702
Moment X	-0.1433
Moment Y (Twist)	0.1974
Moment Z	42.7138

#### 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	11.0964
Shear X	-3.0650
Shear Z	-0.0418
Moment X	-0.0833
Moment Y (Twist)	0.1152
Moment Z	25.0818

#### 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	-0.0369	2.3713	0.0086	0.0170	-0.0210	0.3102
ULS: 2. D + L	-0.0369	2.3713	0.0086	0.0170	-0.0210	0.3102
ULS: 3. D + (S or Lr or R)	-0.1808	9.6456	0.0419	0.0831	-0.1025	1.4666
ULS: 3. D + (S or Lr or R)	-0.0369	2.3713	0.0086	0.0170	-0.0210	0.3102
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1449	7.8270	0.0336	0.0666	-0.0821	1.1775
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0369	2.3713	0.0086	0.0170	-0.0210	0.3102
ULS: 5b. D + 0.7E	-0.0369	2.3713	0.0086	0.0170	-0.0210	0.3102
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1449	7.8270	0.0336	0.0666	-0.0821	1.1775
ULS: 8. 0.6D + 0.7E	-0.0222	1.4228	0.0051	0.0102	-0.0126	0.1861
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0650	6.7305	0.0176	0.0391	-0.0175	25.0818
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.0650	6.7305	0.0176	0.0391	-0.0175	25.0818
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5194	-1.3080	-0.0004	-0.0038	-0.0199	-19.9441
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0728	-0.6817	0.0148	0.0229	-0.0645	-24.8233
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4159	11.0964	0.0404	0.0831	-0.0795	19.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4159	11.0964	0.0404	0.0831	-0.0795	19.7562
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7724	5.0676	0.0268	0.0510	-0.0812	-14.0133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4375	5.5372	0.0383	0.0709	-0.1147	-17.6727

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3080	5.6407	0.0154	0.0336	-0.0184	18.8889
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3080	5.6407	0.0154	0.0336	-0.0184	18.8889
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8803	-0.3881	0.0018	0.0014	-0.0202	-14.8805
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5454	0.0815	0.0133	0.0214	-0.0536	-18.5399
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0502	5.7819	0.0142	0.0323	-0.0091	24.9577
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.0502	5.7819	0.0142	0.0323	-0.0091	24.9577
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5342	-2.2565	-0.0039	-0.0106	-0.0115	-20.0682
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0876	-1.6303	0.0114	0.0160	-0.0561	-24.9474

#### 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	18.1167
Shear X	-5.1624
Shear Z	0.0704
Moment X	0.1421
Moment Y (Twist)	0.1953
Moment Z	42.7138

#### 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	11.0964
Shear X	-3.0650
Shear Z	0.0419
Moment X	0.0831
Moment Y (Twist)	0.1147
Moment Z	25.0818

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

##### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0369	1.7889	-0.1028	-0.1964	0.0555	-0.2540
ULS: 2. D + L	0.0369	1.7889	-0.1028	-0.1964	0.0555	-0.2540
ULS: 3. D + (S or Lr or R)	0.1808	6.7969	-0.5054	-0.9706	0.2742	-1.3287
ULS: 3. D + (S or Lr or R)	0.0369	1.7889	-0.1028	-0.1964	0.0555	-0.2540
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1449	5.5449	-0.4047	-0.7771	0.2195	-1.0600
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0369	1.7889	-0.1028	-0.1964	0.0555	-0.2540
ULS: 5b. D + 0.7E	0.0369	1.7889	-0.1028	-0.1964	0.0555	-0.2540
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1449	5.5449	-0.4047	-0.7771	0.2195	-1.0600
ULS: 8. 0.6D + 0.7E	0.0222	1.0733	-0.0617	-0.1178	0.0333	-0.1524
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.0305	4.7069	-0.4037	-0.7130	0.8308	16.9737
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.0305	4.7069	-0.4037	-0.7130	0.8308	16.9737
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7799	-0.6719	0.1477	0.2338	-0.5908	-14.3948
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5100	-0.2748	0.1310	0.2039	-0.5566	-18.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4057	7.7334	-0.6304	-1.1645	0.8010	11.8607
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4057	7.7334	-0.6304	-1.1645	0.8010	11.8607
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4521	3.6993	-0.2169	-0.4544	-0.2653	-11.6656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2496	3.9971	-0.2294	-0.4768	-0.2396	-14.5605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5136	3.9774	-0.3285	-0.5839	0.6370	12.6668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5136	3.9774	-0.3285	-0.5839	0.6370	12.6668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3442	-0.0567	0.0851	0.1262	-0.4293	-10.8596
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1417	0.2411	0.0725	0.1038	-0.4036	-13.7545
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0453	3.9913	-0.3626	-0.6344	0.8086	17.0753
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0453	3.9913	-0.3626	-0.6344	0.8086	17.0753
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7652	-1.3875	0.1888	0.3123	-0.6131	-14.2932
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4952	-0.9904	0.1721	0.2825	-0.5789	-18.1531

#### Worst Case Reactions LRFD

#### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	12.5916
Shear X	-3.4458
Shear Z	-1.0254
Moment X	-1.9281
Moment Y (Twist)	1.4735
Moment Z	31.1143

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

Result	Value (kip, kip-ft)
Axial	7.7334
Shear X	-2.0453
Shear Z	-0.6304
Moment X	-1.1645
Moment Y (Twist)	0.8308
Moment Z	18.2547

## Project Details

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



## Design Input Information

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

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

### Section Dimensions



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



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



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

### Section Properties

ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	$I_{yp}$ (in <sup>4</sup> )	$I_{zp}$ (in <sup>4</sup> )	$I_w$ (in <sup>6</sup> )	$S_{yp}$ (in <sup>3</sup> )	$S_{zp}$ (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
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21



108	20	1.33	1.33	2.0 5	2.39,2.38,2.39,2.38,2.38,2.39,2.37,2.37,2.34,1.67,2.37,2.37,2.36,1.17,2.37,2.37,2.39,2.14,2.3 7,2.37,2.35,1.38,2.37,2.37,2.36,1.32	3 0 0	2 0 0	1
109	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
110	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.59,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.73,1.67,1.67,1.66,1.64	3 0 0	2 0 0	1
111	20	1.33	1.33	2.0 5	2.11,2.11,2.11,2.11,2.11,2.11,2.07,2.07,1.50,1.48,2.06,2.06,1.88,1.68,2.09,2.09,2.36,2.25,2.0 7,2.07,1.67,1.56,2.06,2.06,1.93,1.71	3 0 0	2 0 0	1
112	6	4.20	4.20	2.0 0	-	3 0 0	2 0 0	1
113	20	4.88	4.00	7.5 0	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.12,1.22,1.07,1.07,1.08,1.10,1.07,1.07,1.06,1.05,1.0 7,1.07,1.09,1.15,1.07,1.07,1.08,1.10	3 0 0	2 0 0	1
114	20	4.88	4.00	7.5 0	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.33,1.06,1.06,1.07,1.05,1.06,1.06,1.06,1.06,1.0 6,1.06,1.07,3.48,1.06,1.06,1.07,1.05	3 0 0	2 0 0	1
115	20	6.63	6.63	10. 20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.09,1.09,1.13,1.13,1.12,1.11,1.14,1.14,1.16,1.20,1.1 3,1.13,1.11,1.10,1.13,1.13,1.12,1.11	3 0 0	2 0 0	1
116	20	6.63	6.63	10. 20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.10,1.17,1.17,1.17,1.77,1.16,1.16,1.16,1.15,1.1 6,1.16,1.17,1.08,1.17,1.17,1.17,1.52	3 0 0	2 0 0	1
201	9	16.9 3	16.9 3	8.0 6	-	3 0 0	2 0 0	1
202	6	4.20	4.20	2.0 0	-	3 0 0	2 0 0	1
203	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.1 8,1.18,1.17,1.17,1.18,1.18,1.18,1.18	3 0 0	2 0 0	1
204	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.59,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.73,1.67,1.67,1.66,1.64	3 0 0	2 0 0	1
205	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
206	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.1 8,1.18,1.17,1.17,1.18,1.18,1.18,1.18	3 0 0	2 0 0	1
207	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
208	20	1.33	1.33	2.0 5	2.01,2.02,2.01,2.03,2.01,2.01,2.04,2.04,2.07,1.43,2.05,2.05,2.06,1.39,2.04,2.04,2.01,1.90,2.0 4,2.04,2.07,1.25,2.05,2.05,2.05,1.66	3 0 0	2 0 0	1
209	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
210	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.60,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.73,1.67,1.67,1.66,1.64	3 0 0	2 0 0	1
211	20	1.33	1.33	2.0 5	1.85,1.86,1.85,1.85,1.86,1.85,1.64,1.64,1.34,1.33,1.61,1.61,1.53,1.44,1.74,1.74,2.07,2.11,1.6 4,1.64,1.43,1.38,1.60,1.60,1.54,1.45	3 0 0	2 0 0	1
212	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
213	20	4.88	4.00	7.5 0	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.12,1.22,1.07,1.07,1.08,1.10,1.07,1.07,1.06,1.05,1.0 7,1.07,1.09,1.15,1.07,1.07,1.08,1.10	3 0 0	2 0 0	1
214	20	4.88	4.00	7.5 0	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.33,1.06,1.06,1.07,1.05,1.06,1.06,1.06,1.06,1.0 6,1.06,1.07,3.48,1.06,1.06,1.07,1.05	3 0 0	2 0 0	1
215	20	6.63	6.63	10. 20	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.11,1.11,1.14,1.14,1.14,1.12,1.16,1.16,1.18,1.22,1.1 5,1.15,1.12,1.12,1.14,1.14,1.14,1.13	3 0 0	2 0 0	1
216	20	6.63	6.63	10. 20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.12,1.18,1.18,1.18,1.74,1.18,1.18,1.18,1.17,1.1 8,1.18,1.19,1.10,1.18,1.18,1.18,3.31	3 0 0	2 0 0	1
301	9	16.9 3	16.9 3	8.0 6	-	3 0 0	2 0 0	1

302	6	4.20	4.20	2.0 0	-	3 0 0	2 0 0	1
303	17	0.92	0.92	1.4 2	1.20,1.19,1.20,1.18,1.19,1.20,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.1 9,1.19,1.17,1.18,1.19,1.19,1.18,1.18	3 0 0	2 0 0	1
304	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.58,1.67,1.67,1.68,1.67,1.6 8,1.68,1.64,1.74,1.67,1.67,1.66,1.63	3 0 0	2 0 0	1
305	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.6 7,1.67,1.65,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
306	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.15,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.1 8,1.18,1.15,1.16,1.17,1.17,1.16,1.17	3 0 0	2 0 0	1
307	17	1.52	1.52	2.3 3	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.6 7,1.67,1.64,1.65,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
308	20	2.10	2.10	1.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.32,2.33,2.33,2.33,2.33	3 0 0	2 0 0	1
309	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
310	17	2.44	2.44	3.7 5	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.64,1.69,1.67,1.67,1.65,2.06,1.67,1.67,1.68,1.67,1.6 8,1.68,1.62,1.73,1.67,1.67,1.66,1.49	3 0 0	2 0 0	1
311	20	2.10	2.10	1.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33,2.33,2.33	3 0 0	2 0 0	1
312	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
313	20	4.88	4.00	7.5 0	1.53,1.55,1.53,1.56,1.54,1.53,1.41,1.41,1.29,1.41,1.38,1.38,1.34,1.41,1.50,1.50,1.67,1.86,1.4 0,1.40,1.32,1.41,1.37,1.37,1.35,1.41	3 0 0	2 0 0	1
314	20	4.88	4.00	7.5 0	1.64,1.68,1.64,1.70,1.67,1.64,1.83,1.83,2.35,1.71,1.86,1.86,1.98,2.81,1.76,1.76,1.61,1.59,1.8 2,1.82,2.19,2.04,1.87,1.87,1.95,2.97	3 0 0	2 0 0	1
315	20	6.63	6.63	10. 20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.08,1.0 8,1.08,1.08,1.09,1.08,1.08,1.07,1.08	3 0 0	2 0 0	1
316	20	6.63	6.63	10. 20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.10,1.08,1.08,1.08,1.36,1.08,1.08,1.08,1.08,1.0 8,1.08,1.08,1.14,1.08,1.08,1.08,1.16	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	377.97	266.41	83.29	83.29	113.39	113.39
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	39.41	6.46	56.26	44.91
14	159.30	116.35	46.90	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	377.97	266.41	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95

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	229.64	27.16	27.16	75.30	75.30
113	159.30	116.35	32.05	6.46	56.26	44.91
114	159.30	116.35	32.02	6.46	56.26	44.91
115	159.30	75.13	20.97	6.46	56.26	44.91
116	159.30	75.13	20.73	6.46	56.26	44.91
201	377.97	266.41	83.29	83.29	113.39	113.39
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	142.47	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	142.47	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	32.05	6.46	56.26	44.91
214	159.30	116.35	32.00	6.46	56.26	44.91
215	159.30	75.13	21.34	6.46	56.26	44.91
216	159.30	75.13	21.14	6.46	56.26	44.91
301	377.97	266.41	83.29	83.29	113.39	113.39
302	251.01	229.64	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	137.23	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	137.23	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	39.39	6.46	56.26	44.91
314	159.30	116.35	46.90	6.46	56.26	44.91
315	159.30	75.13	20.69	6.46	56.26	44.91
316	159.30	75.13	20.69	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	φ	Status
1	0.047	0.374	0.076	0.030	0.009	0.376	#16	0.346	Not Required	Pass
2	0.003	0.241	0.097	0.059	0.021	0.312	#21	0.054	Not Required	Pass
3	0.007	0.405	0.025	0.039	0.009	0.415	#21	0.046	Not Required	Pass
4	0.005	0.308	0.083	0.040	0.010	0.403	#21	0.123	Not Required	Pass

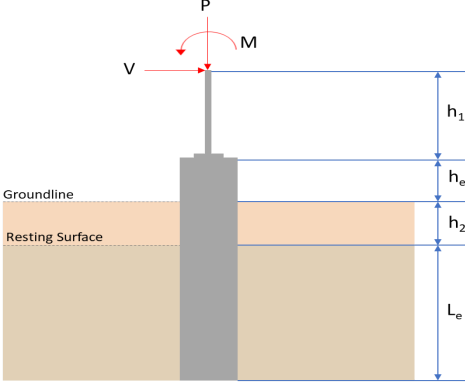
4	0.005	0.398	0.082	0.040	0.019	0.482	#21	0.122	Not Required	Pass
5	0.006	0.251	0.031	0.040	0.008	0.255	#21	0.076	Not Required	Pass
6	0.013	0.613	0.150	0.063	0.042	0.769	#21	0.046	Not Required	Pass
7	0.014	0.380	0.227	0.060	0.057	0.436	#21	0.076	Not Required	Pass
8	0.005	0.140	0.231	0.035	0.027	0.284	#21	0.102	Not Required	Pass
9	0.007	0.043	0.112	0.003	0.007	0.143	#21	0.206	Not Required	Pass
10	0.015	0.586	0.198	0.059	0.042	0.691	#21	0.082	Not Required	Pass
11	0.010	0.137	0.245	0.037	0.027	0.299	#21	0.102	Not Required	Pass
12	0.001	0.474	0.151	0.104	0.027	0.583	#21	0.174	Not Required	Pass
13	0.013	0.063	0.621	0.049	0.034	0.637	#21	0.306	Not Required	Pass
14	0.005	0.070	0.601	0.047	0.034	0.620	#24	0.204	Not Required	Pass
15	0.000	0.004	0.015	0.007	0.004	0.019	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.015	0.007	0.004	0.019	#21	Not Required	Not Required	Pass
101	0.068	0.513	0.005	0.046	0.001	0.540	#13	0.346	Not Required	Pass
102	0.004	0.535	0.196	0.120	0.034	0.696	#21	0.036	Not Required	Pass
103	0.013	0.756	0.082	0.075	0.011	0.845	#21	0.046	Not Required	Pass
104	0.013	0.756	0.220	0.076	0.047	0.906	#21	0.082	Not Required	Pass
105	0.013	0.469	0.234	0.075	0.061	0.531	#21	0.076	Not Required	Pass
106	0.013	0.746	0.078	0.074	0.010	0.828	#21	0.046	Not Required	Pass
107	0.013	0.464	0.226	0.074	0.058	0.523	#21	0.076	Not Required	Pass
108	0.006	0.049	0.230	0.042	0.027	0.281	#21	0.102	Not Required	Pass
109	0.022	0.055	0.058	0.001	0.000	0.124	#21	0.206	Not Required	Pass
110	0.013	0.735	0.218	0.073	0.048	0.889	#21	0.082	Not Required	Pass
111	0.010	0.051	0.241	0.042	0.027	0.282	#21	0.102	Not Required	Pass
112	0.004	0.519	0.194	0.117	0.034	0.675	#21	0.116	Not Required	Pass
113	0.013	0.223	0.632	0.060	0.035	0.820	#21	0.306	Not Required	Pass
114	0.008	0.247	0.622	0.061	0.035	0.829	#21	0.306	Not Required	Pass
115	0.020	0.385	0.340	0.048	0.027	0.738	#21	0.507	Not Required	Pass
116	0.005	0.373	0.334	0.049	0.027	0.706	#21	0.507	Not Required	Pass
201	0.068	0.513	0.005	0.046	0.001	0.540	#13	0.346	Not Required	Pass
202	0.004	0.519	0.194	0.117	0.034	0.675	#21	0.116	Not Required	Pass
203	0.013	0.746	0.078	0.074	0.010	0.828	#21	0.046	Not Required	Pass
204	0.013	0.735	0.218	0.073	0.048	0.889	#21	0.082	Not Required	Pass
205	0.013	0.464	0.226	0.074	0.058	0.523	#21	0.076	Not Required	Pass
206	0.013	0.756	0.082	0.075	0.011	0.845	#21	0.046	Not Required	Pass
207	0.013	0.469	0.234	0.075	0.061	0.531	#21	0.076	Not Required	Pass
208	0.005	0.075	0.247	0.049	0.027	0.276	#21	0.102	Not Required	Pass
209	0.022	0.055	0.058	0.001	0.000	0.124	#21	0.206	Not Required	Pass
210	0.013	0.756	0.220	0.076	0.047	0.906	#21	0.082	Not Required	Pass
211	0.010	0.086	0.255	0.048	0.027	0.274	#21	0.102	Not Required	Pass
212	0.004	0.535	0.196	0.120	0.034	0.696	#21	0.036	Not Required	Pass
213	0.013	0.223	0.633	0.060	0.035	0.820	#21	0.306	Not Required	Pass
214	0.008	0.247	0.621	0.061	0.035	0.829	#21	0.306	Not Required	Pass
215	0.019	0.249	0.341	0.042	0.027	0.602	#21	0.507	Not Required	Pass
216	0.006	0.217	0.332	0.042	0.027	0.550	#21	0.507	Not Required	Pass
301	0.047	0.374	0.076	0.030	0.009	0.376	#16	0.346	Not Required	Pass
302	0.001	0.474	0.151	0.104	0.027	0.583	#21	0.174	Not Required	Pass
303	0.013	0.613	0.150	0.063	0.042	0.769	#21	0.046	Not Required	Pass
304	0.015	0.586	0.198	0.059	0.042	0.691	#21	0.082	Not Required	Pass
305	0.014	0.380	0.226	0.060	0.057	0.436	#21	0.076	Not Required	Pass
306	0.007	0.405	0.025	0.039	0.009	0.415	#21	0.046	Not Required	Pass
307	0.006	0.251	0.031	0.040	0.008	0.255	#21	0.076	Not Required	Pass
308	0.000	0.004	0.015	0.007	0.004	0.019	#21	Not Required	Not Required	Pass
309	0.007	0.043	0.112	0.003	0.007	0.143	#21	0.206	Not Required	Pass

310	0.005	0.398	0.082	0.040	0.019	0.482	#21	0.122	Not Required	Pass
311	0.000	0.004	0.015	0.007	0.004	0.019	#21	Not Required	Not Required	Pass
312	0.003	0.241	0.097	0.059	0.021	0.312	#21	0.054	Not Required	Pass
313	0.013	0.063	0.620	0.049	0.034	0.637	#21	0.204	Not Required	Pass
314	0.005	0.070	0.601	0.047	0.034	0.620	#24	0.306	Not Required	Pass
315	0.020	0.413	0.340	0.037	0.027	0.753	#21	0.507	Not Required	Pass
316	0.005	0.405	0.332	0.035	0.027	0.727	#21	0.507	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: round <math>D = 36</math> in - Pile diameter <math>L = 7.75</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resisting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <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>7.733</td> <td>12.592</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.045</td> <td>-3.446</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.630</td> <td>1.025</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>1.164</td> <td>1.925</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>18.255</td> <td>31.114</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)	7.733	12.592	$V_x$ (kip)	-2.045	-3.446	$V_z$ (kip)	0.630	1.025	$M_x$ (kipft)	1.164	1.925	$M_z$ (kipft)	18.255	31.114	
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$M_z$ (kipft)	18.255	31.114																										
	<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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.045 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.68167 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(18.255 \text{ kipft}) + ((-2.045 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 6.085 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.865 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.63 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.21 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.164 \text{ kipft}) + ((0.63 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.388 \text{ kipft/ft}$$

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:

$L_{e,z} = 5.3731 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.865 \text{ ft}), (5.3731 \text{ ft})]$$

$$L_{e,req} = 6.865 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.865 \text{ ft})}{(7.75 \text{ ft})}$$

$$\text{Ratio} = 0.88581$$

Status: **PASS**  
Ratio: **0.890**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(7.733 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.094 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.094 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.547$$

Status: **PASS**  
Ratio: **0.550**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.68167 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 6.085 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (6.085 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (6.085 \text{ kipft/ft})) + (4 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4034 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.085 \text{ kipft/ft})) + (3 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (6.085 \text{ kipft/ft})) + (2 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.18391 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (6.085 \text{ kipft/ft})) + ((-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.0807 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.4034 \text{ ft})}{2}$$

$$p_a = 0.40526 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.18391 \text{ kip/ft}^2)}{(0.40526 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.45381$$

Status: **PASS**  
Ratio: **0.450**

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.0807 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92965$$

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

**Considering z-direction:**

$H_o = 0.21 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.388 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.388 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.21 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.388 \text{ kipft/ft})) + (4 \times (0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6424 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.388 \text{ kipft/ft})) + (3 \times (0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.388 \text{ kipft/ft})) + (2 \times (0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.18376 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.388 \text{ kipft/ft})) + ((0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 0.37716 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.6424 \text{ ft})}{2}$$

$$p_a = 0.42318 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.18376 \text{ kip/ft}^2)}{(0.42318 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.43423$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

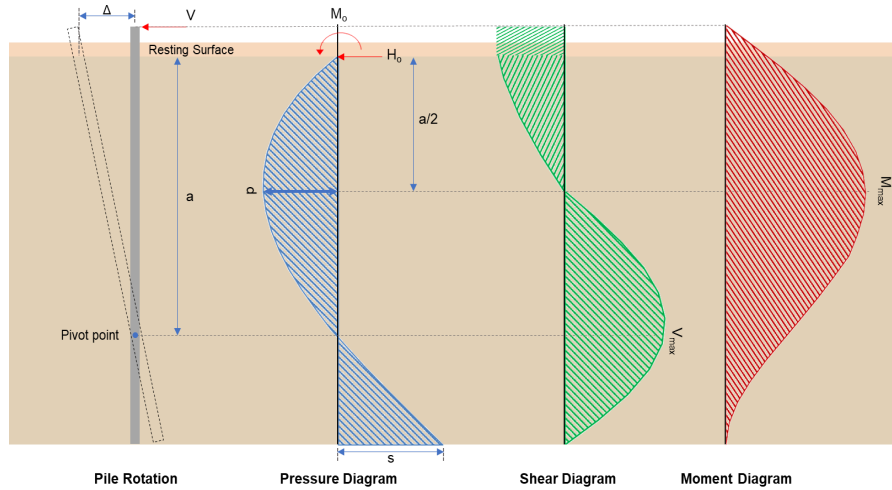
Status: **PASS**  
Ratio: **0.430**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(0.37716 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$Ratio = 0.32444$$

Status: **PASS**  
Ratio: **0.320**



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.446 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1487 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(31.114 \text{ kipft}) + ((-3.446 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.371 \text{ kipft/ft}$$

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

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

$$E = \frac{(10.371 \text{ kipft/ft})}{(-1.1487 \text{ kip/ft})}$$

$$E = 9.029 \text{ ft}$$

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

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

$$a = \frac{(4 \times (10.371 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-1.1487 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (10.371 \text{ kipft/ft})) + (4 \times (-1.1487 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4017 \text{ ft}$$

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

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

$$V_{max} = ((-1.1487 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.4017 \text{ ft})}{(7.75 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.4017 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.3777 \text{ kip}$$

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

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

$$M_{max} = ((-1.1487 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(9.029 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 33.927 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(1.025 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.34167 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.925 \text{ kipft}) + ((1.025 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.64167 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.64167 \text{ kipft/ft})}{(0.34167 \text{ kip/ft})}$$

$$E = 1.878 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.64167 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (0.34167 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.64167 \text{ kipft/ft})) + (4 \times (0.34167 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6403 \text{ ft}$$

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

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

$$V_{max} = ((0.34167 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (1.878 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.6403 \text{ ft})}{(7.75 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (1.878 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.6403 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 1.13 \text{ kip}$$

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

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

$$M_{max} = ((0.34167 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(1.878 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.6403 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (1.878 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.6403 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (1.878 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.6403 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 3.6762 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.85$  - Alpha factor for axial strength,  
 $A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.592 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.98 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-36.98 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.99533$$

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 $\varnothing$ : Use #3(0.375 in)

25.7.2.1

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

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

#### Summary:

Status: **PASS**  
Ratio: **1.000**

Main reinforcement: **6 - #5 (0.625 in)**  
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.592 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.010042$$

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

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

**Parameters:**

22.5.2.2

$b_w = 36 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.592 \text{ kip} \rightarrow 12592 \text{ lbf}$ .

22.5.5.1.1(a)

$V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(12592 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.576 \text{ kip}$$

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)

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

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

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

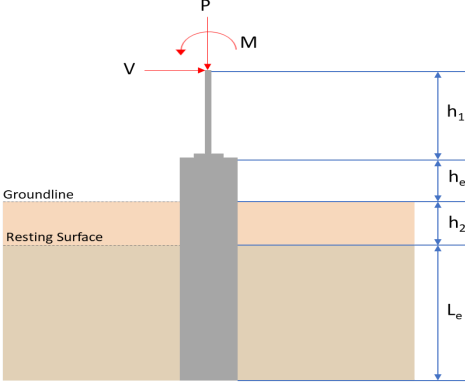
$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.576 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 76.576 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <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><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((76.576 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.585 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 9.3777 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(9.3777 \text{ kip})}{(74.585 \text{ kip})}$ $Ratio = 0.12573$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 1.13 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(1.13 \text{ kip})}{(74.585 \text{ kip})}$ $Ratio = 0.01515$	<p>Status: <b>PASS</b> Ratio: <b>0.130</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.020</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;"><math>S_m = 4580.4 \text{ in}^3</math></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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 33.927 \text{ kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(33.927 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.54697$	<p>Status: <b>PASS</b>  Ratio: <b>0.550</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 3.6762 \text{ kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.6762 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.059267$	<p>Status: <b>PASS</b>  Ratio: <b>0.060</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: round <math>D = 36</math> in - Pile diameter <math>L = 7.75</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resisting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <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>7.733</td> <td>12.592</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.045</td> <td>-3.446</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.630</td> <td>-1.025</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-1.165</td> <td>-1.928</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>18.255</td> <td>31.114</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)	7.733	12.592	$V_x$ (kip)	-2.045	-3.446	$V_z$ (kip)	-0.630	-1.025	$M_x$ (kipft)	-1.165	-1.928	$M_z$ (kipft)	18.255	31.114	
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$M_x$ (kipft)	-1.165	-1.928																										
$M_z$ (kipft)	18.255	31.114																										
	<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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.045 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.68167 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(18.255 \text{ kipft}) + ((-2.045 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 6.085 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.865 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.63 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.21 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.165 \text{ kipft}) + ((-0.63 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.38833 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.0377 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.865 \text{ ft}), (2.0377 \text{ ft})]$$

$$L_{e,req} = 6.865 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.865 \text{ ft})}{(7.75 \text{ ft})}$$

$$\text{Ratio} = 0.88581$$

Status: **PASS**  
Ratio: **0.890**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(7.733 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.094 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.094 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.547$$

Status: **PASS**  
Ratio: **0.550**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 2.5833$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.68167 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 6.085 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (6.085 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (6.085 \text{ kipft/ft})) + (4 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4034 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (6.085 \text{ kipft/ft})) + (3 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (6.085 \text{ kipft/ft})) + (2 \times (-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.18391 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (6.085 \text{ kipft/ft})) + ((-0.68167 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.0807 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.4034 \text{ ft})}{2}$$

$$p_a = 0.40526 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.18391 \text{ kip/ft}^2)}{(0.40526 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.45381$$

Status: **PASS**  
Ratio: **0.450**

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.0807 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92965$$

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

**Considering z-direction:**

$H_o = -0.21 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.38833 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.38833 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.21 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.38833 \text{ kipft/ft})) + (4 \times (-0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6423 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.38833 \text{ kipft/ft})) + (3 \times (-0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (0.38833 \text{ kipft/ft})) + (2 \times (-0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = -0.10401 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.38833 \text{ kipft/ft})) + ((-0.21 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = -0.13351 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.6423 \text{ ft})}{2}$$

$$p_a = 0.42317 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.10401 \text{ kip/ft}^2)}{(0.42317 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.24578$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

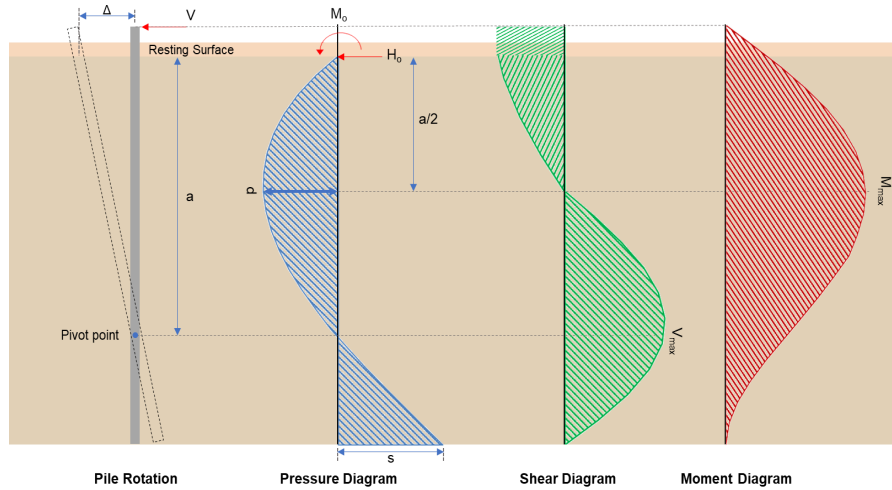
Status: **PASS**  
Ratio: **-0.250**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(-0.13351 \text{ kip/ft}^2)}{(1.1625 \text{ kip/ft}^2)}$$

$$Ratio = -0.11485$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.446 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1487 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(31.114 \text{ kipft}) + ((-3.446 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.371 \text{ kipft/ft}$$

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

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

$$E = \frac{(10.371 \text{ kipft/ft})}{(-1.1487 \text{ kip/ft})}$$

$$E = 9.029 \text{ ft}$$

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

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

$$a = \frac{(4 \times (10.371 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-1.1487 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (10.371 \text{ kipft/ft})) + (4 \times (-1.1487 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.4017 \text{ ft}$$

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

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

$$V_{max} = ((-1.1487 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.4017 \text{ ft})}{(7.75 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.4017 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.3777 \text{ kip}$$

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

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

$$M_{max} = ((-1.1487 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(9.029 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (9.029 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.4017 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 33.927 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.025 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.34167 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.928 \text{ kipft}) + ((-1.025 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.64267 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.64267 \text{ kipft/ft})}{(-0.34167 \text{ kip/ft})}$$

$$E = 1.881 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.64267 \text{ kipft/ft}) \times (7.75 \text{ ft})) + (3 \times (-0.34167 \text{ kip/ft}) \times (7.75 \text{ ft})^2)}{(6 \times (0.64267 \text{ kipft/ft})) + (4 \times (-0.34167 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.6401 \text{ ft}$$

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

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

$$V_{max} = ((-0.34167 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (1.881 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.6401 \text{ ft})}{(7.75 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (1.881 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.6401 \text{ ft})}{(7.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 1.1307 \text{ kip}$$

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

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

$$M_{max} = ((-0.34167 \text{ kip/ft}) \times (36 \text{ in}) \times (7.75 \text{ ft})) \times \left[ \left( \frac{(1.881 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.6401 \text{ ft})}{2 \times (7.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (1.881 \text{ ft})}{(7.75 \text{ ft})} + 3 \right) \times \left( \frac{(5.6401 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (1.881 \text{ ft})}{(7.75 \text{ ft})} + 2 \right) \times \left( \frac{(5.6401 \text{ ft})}{2 \times (7.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 3.6787 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.85$  - Alpha factor for axial strength,  
 $A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.592 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.98 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-36.98 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.99533$$

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 $\varnothing$ : Use #3(0.375 in)

25.7.2.1

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

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

#### Summary:

Status: **PASS**  
Ratio: **1.000**

Main reinforcement: **6 - #5 (0.625 in)**  
Ties: **#3(0.375 in) - 10 in**

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.592 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.010042$$

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

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

**Parameters:**

22.5.2.2

$b_w = 36 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.592 \text{ kip} \rightarrow 12592 \text{ lbf}$ .

22.5.5.1.1(a)

$V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(12592 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.576 \text{ kip}$$

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)

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

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

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

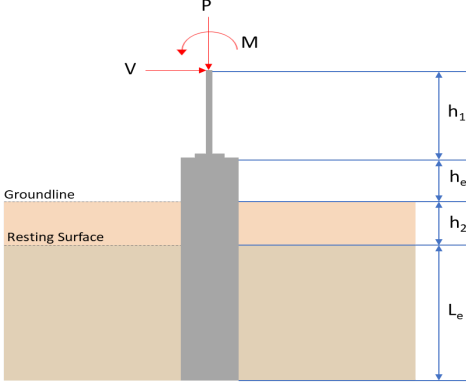
$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.576 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 76.576 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <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><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((76.576 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.585 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 9.3777 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(9.3777 \text{ kip})}{(74.585 \text{ kip})}$ $Ratio = 0.12573$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 1.1307 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(1.1307 \text{ kip})}{(74.585 \text{ kip})}$ $Ratio = 0.015159$	<p>Status: <b>PASS</b> Ratio: <b>0.130</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.020</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

	<p style="text-align: center;"><math>S_m = 4580.4 \text{ in}^3</math></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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 33.927 \text{ kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(33.927 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.54697$	<p>Status: <b>PASS</b>  Ratio: <b>0.550</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 3.6787 \text{ kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.6787 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.059309$	<p>Status: <b>PASS</b>  Ratio: <b>0.060</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: round <math>D = 36</math> in - Pile diameter <math>L = 8.25</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 resisting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <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>11.096</td> <td>18.117</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-3.065</td> <td>-5.162</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.042</td> <td>-0.070</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.083</td> <td>-0.143</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>25.082</td> <td>42.714</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)	11.096	18.117	$V_x$ (kip)	-3.065	-5.162	$V_z$ (kip)	-0.042	-0.070	$M_x$ (kipft)	-0.083	-0.143	$M_z$ (kipft)	25.082	42.714	
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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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-3.065 \text{ kip})}{(36 \text{ in})}$ $H_o = -1.0217 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(25.082 \text{ kipft}) + ((-3.065 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.3607 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.136 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.042 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.014 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.083 \text{ kipft}) + ((-0.042 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.027667 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.2288 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(7.136 \text{ ft}), (1.2288 \text{ ft})]$$

$$L_{e,req} = 7.136 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(7.136 \text{ ft})}{(8.25 \text{ ft})}$$

$$\text{Ratio} = 0.86497$$

Status: **PASS**  
Ratio: **0.860**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(11.096 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.5698 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.5698 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.78488$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -1.0217 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 8.3607 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (8.3607 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (8.3607 \text{ kipft/ft})) + (4 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7763 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.3607 \text{ kipft/ft})) + (3 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (8.3607 \text{ kipft/ft})) + (2 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.14 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (8.3607 \text{ kipft/ft})) + ((-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 1.1483 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7763 \text{ ft})}{2}$$

$$p_a = 0.43323 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.14 \text{ kip/ft}^2)}{(0.43323 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.32316$$

Status: **PASS**  
Ratio: **0.320**

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$

$$p_s = 1.2375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1483 \text{ kip/ft}^2)}{(1.2375 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92794$$

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

**Considering z-direction:**

$H_o = -0.014 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.027667 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.027667 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-0.014 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (0.027667 \text{ kipft/ft})) + (4 \times (-0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 6.0058 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.027667 \text{ kipft/ft})) + (3 \times (-0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (0.027667 \text{ kipft/ft})) + (2 \times (-0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = -0.0065041 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.027667 \text{ kipft/ft})) + ((-0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = -0.0083316 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0058 \text{ ft})}{2}$$

$$p_a = 0.45043 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0065041 \text{ kip/ft}^2)}{(0.45043 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.01444$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$

$$p_s = 1.2375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

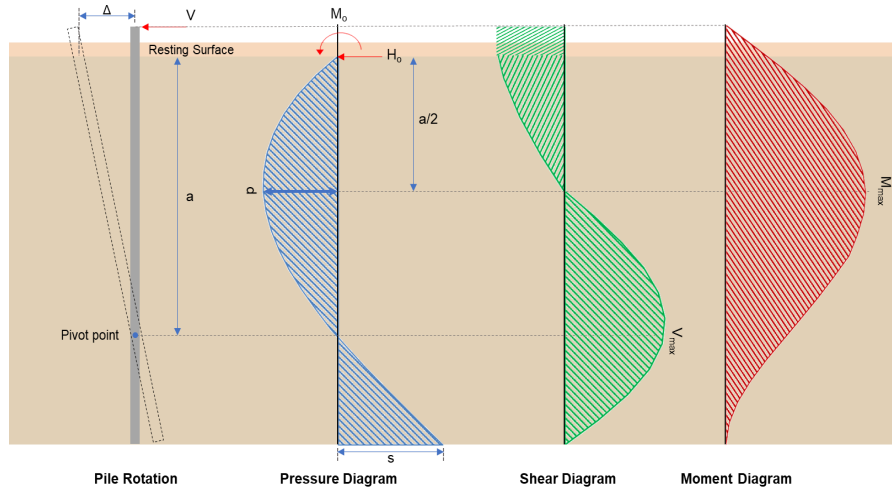
Status: **PASS**  
Ratio: **-0.010**

$$ratio = \frac{-}{p_s}$$

$$Ratio = \frac{(-0.0083316 \text{ kip/ft}^2)}{(1.2375 \text{ kip/ft}^2)}$$

$$Ratio = -0.0067326$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.162 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.7207 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(42.714 \text{ kipft}) + ((-5.162 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.238 \text{ kipft/ft}$$

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

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

$$E = \frac{(14.238 \text{ kipft/ft})}{(-1.7207 \text{ kip/ft})}$$

$$E = 8.2747 \text{ ft}$$

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

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

$$a = \frac{(4 \times (14.238 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-1.7207 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (14.238 \text{ kipft/ft})) + (4 \times (-1.7207 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7745 \text{ ft}$$

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

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

$$V_{max} = ((-1.7207 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.7745 \text{ ft})}{(8.25 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.7745 \text{ ft})}{(8.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.571 \text{ kip}$$

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

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

$$M_{max} = ((-1.7207 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[ \left( \frac{(8.2747 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 48.018 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.07 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.023333 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.143 \text{ kipft}) + ((-0.07 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.047667 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.047667 \text{ kipft/ft})}{(-0.023333 \text{ kip/ft})}$$

$$E = 2.0429 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.047667 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-0.023333 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (0.047667 \text{ kipft/ft})) + (4 \times (-0.023333 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 6.0013 \text{ ft}$$

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

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

$$V_{max} = ((-0.023333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.0429 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(6.0013 \text{ ft})}{(8.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (2.0429 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(6.0013 \text{ ft})}{(8.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.077811 \text{ kip}$$

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

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

$$M_{max} = ((-0.023333 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[ \left( \frac{(2.0429 \text{ ft})}{(8.25 \text{ ft})} + \frac{(6.0013 \text{ ft})}{2 \times (8.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (2.0429 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(6.0013 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.0429 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(6.0013 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.26988 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

- $f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,
- $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,
- $\phi = 0.65$  - Reduction factor for axial strength,
- $\alpha = 0.85$  - Alpha factor for axial strength,
- $A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

**Longitudinal reinforcement:**

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(18.117 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.807 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-36.807 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

**Ratio** - Capacity

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

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

$$\text{Ratio} = 0.99533$$

Status: **PASS**  
Ratio: **1.000**

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 $\varnothing$ : Use #3(0.375 in)

25.7.2.1

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

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[ (0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2)) \right]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(18.117 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.014448$$

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

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

**Parameters:**

22.5.2.2

$b_w = 36 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 18.117 \text{ kip} \rightarrow 18117 \text{ lbf}$ .

22.5.5.1.1(a)

$V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(18117 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.514 \text{ kip}$$

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)

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

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

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

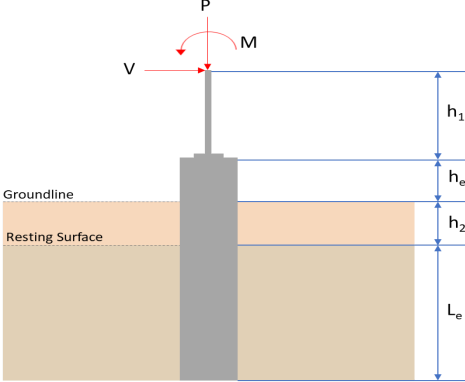
$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min} [(186.09 \text{ kip}), (77.514 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 77.514 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <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><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.514 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 75.195 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 12.571 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(12.571 \text{ kip})}{(75.195 \text{ kip})}$ $Ratio = 0.16718$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.077811 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.077811 \text{ kip})}{(75.195 \text{ kip})}$ $Ratio = 0.0010348$	<p>Status: <b>PASS</b> Ratio: <b>0.170</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> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;"><math>S_m = 4580.4 \text{ in}^3</math></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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 48.018 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(48.018 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.77415$	<p>Status: <b>PASS</b>          Ratio: <b>0.770</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.26988 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.26988 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.0043511$	<p>Status: <b>PASS</b>          Ratio: <b>0.000</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: round <math>D = 36</math> in - Pile diameter <math>L = 8.25</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 resisting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <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>11.096</td> <td>18.117</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-3.065</td> <td>-5.162</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.042</td> <td>0.070</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.083</td> <td>0.142</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>25.082</td> <td>42.714</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)	11.096	18.117	$V_x$ (kip)	-3.065	-5.162	$V_z$ (kip)	0.042	0.070	$M_x$ (kipft)	0.083	0.142	$M_z$ (kipft)	25.082	42.714	
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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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-3.065 \text{ kip})}{(36 \text{ in})}$ $H_o = -1.0217 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(25.082 \text{ kipft}) + ((-3.065 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.3607 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.136 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.042 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.014 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.083 \text{ kipft}) + ((0.042 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.027667 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.8025 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(7.136 \text{ ft}), (1.8025 \text{ ft})]$$

$$L_{e,req} = 7.136 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.25 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(7.136 \text{ ft})}{(8.25 \text{ ft})}$$

$$\text{Ratio} = 0.86497$$

Status: **PASS**  
Ratio: **0.860**

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(11.096 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.5698 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.5698 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.78488$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(8.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -1.0217 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 8.3607 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (8.3607 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (8.3607 \text{ kipft/ft})) + (4 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7763 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.3607 \text{ kipft/ft})) + (3 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (8.3607 \text{ kipft/ft})) + (2 \times (-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.14 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (8.3607 \text{ kipft/ft})) + ((-1.0217 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 1.1483 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7763 \text{ ft})}{2}$$

$$p_a = 0.43323 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.14 \text{ kip/ft}^2)}{(0.43323 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.32316$$

Status: **PASS**  
Ratio: **0.320**

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$

$$p_s = 1.2375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1483 \text{ kip/ft}^2)}{(1.2375 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.92794$$

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

**Considering z-direction:**

$H_o = 0.014 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.027667 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.027667 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (0.014 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (0.027667 \text{ kipft/ft})) + (4 \times (0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 6.0058 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.027667 \text{ kipft/ft})) + (3 \times (0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (0.027667 \text{ kipft/ft})) + (2 \times (0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.01152 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.027667 \text{ kipft/ft})) + ((0.014 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 0.023656 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0058 \text{ ft})}{2}$$

$$p_a = 0.45043 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.01152 \text{ kip/ft}^2)}{(0.45043 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.025576$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$

$$p_s = 1.2375 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

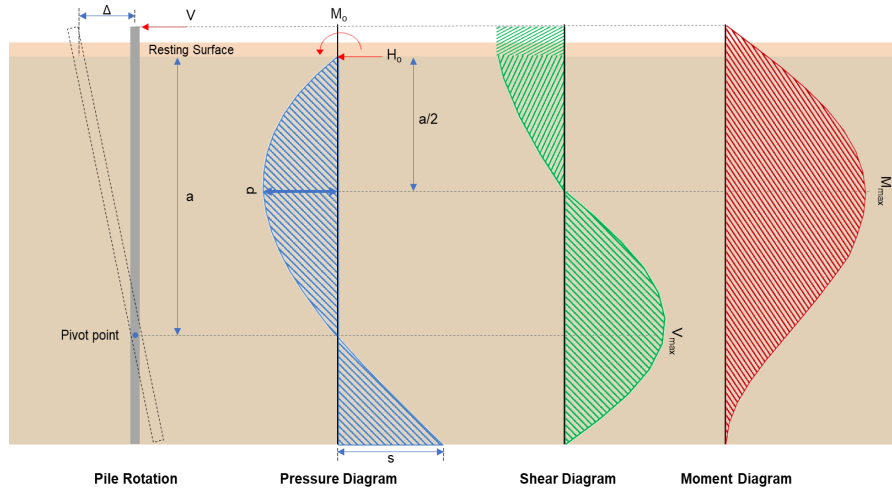
Status: **PASS**  
Ratio: **0.030**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(0.023656 \text{ kip/ft}^2)}{(1.2375 \text{ kip/ft}^2)}$$

$$Ratio = 0.019116$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.162 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.7207 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(42.714 \text{ kipft}) + ((-5.162 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.238 \text{ kipft/ft}$$

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

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

$$E = \frac{(14.238 \text{ kipft/ft})}{(-1.7207 \text{ kip/ft})}$$

$$E = 8.2747 \text{ ft}$$

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

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

$$a = \frac{(4 \times (14.238 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (-1.7207 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (14.238 \text{ kipft/ft})) + (4 \times (-1.7207 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7745 \text{ ft}$$

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

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

$$V_{max} = ((-1.7207 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.7745 \text{ ft})}{(8.25 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.7745 \text{ ft})}{(8.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 12.571 \text{ kip}$$

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

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

$$M_{max} = ((-1.7207 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[ \left( \frac{(8.2747 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (8.2747 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(5.7745 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 48.018 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.07 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.023333 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.142 \text{ kipft}) + ((0.07 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.047333 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.047333 \text{ kipft/ft})}{(0.023333 \text{ kip/ft})}$$

$$E = 2.0286 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.047333 \text{ kipft/ft}) \times (8.25 \text{ ft})) + (3 \times (0.023333 \text{ kip/ft}) \times (8.25 \text{ ft})^2)}{(6 \times (0.047333 \text{ kipft/ft})) + (4 \times (0.023333 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 6.0023 \text{ ft}$$

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

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

$$V_{max} = ((0.023333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.0286 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(6.0023 \text{ ft})}{(8.25 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (2.0286 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(6.0023 \text{ ft})}{(8.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.077601 \text{ kip}$$

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

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

$$M_{max} = ((0.023333 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[ \left( \frac{(2.0286 \text{ ft})}{(8.25 \text{ ft})} + \frac{(6.0023 \text{ ft})}{2 \times (8.25 \text{ ft})} \right) - \left[ \left( \frac{4 \times (2.0286 \text{ ft})}{(8.25 \text{ ft})} + 3 \right) \times \left( \frac{(6.0023 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (2.0286 \text{ ft})}{(8.25 \text{ ft})} + 2 \right) \times \left( \frac{(6.0023 \text{ ft})}{2 \times (8.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.26902 \text{ kipft}$$

**Minimum Reinforcement Check (LRFD)**

**Parameters:**

- $f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,
- $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,
- $\phi = 0.65$  - Reduction factor for axial strength,
- $\alpha = 0.85$  - Alpha factor for axial strength,
- $A_g = 1017.9 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

**Longitudinal reinforcement:**

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(18.117 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.807 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-36.807 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 6$$

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

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

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

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

**Ratio** - Capacity

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

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

$$\text{Ratio} = 0.99533$$

Status: **PASS**  
Ratio: **1.000**

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 $\varnothing$ : Use #3(0.375 in)

25.7.2.1

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

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

**Summary:**

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[ (0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2)) \right]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(18.117 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.014448$$

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

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

**Parameters:**

22.5.2.2

$b_w = 36 \text{ in}$  - Effective width,  
 $d$  - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[ \sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 18.117 \text{ kip} \rightarrow 18117 \text{ lbf}$ .

22.5.5.1.1(a)

$V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(18117 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.514 \text{ kip}$$

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)

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min} [(186.09 \text{ kip}), (77.514 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 77.514 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <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><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.514 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 75.195 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 12.571 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(12.571 \text{ kip})}{(75.195 \text{ kip})}$ $Ratio = 0.16718$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.077601 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.077601 \text{ kip})}{(75.195 \text{ kip})}$ $Ratio = 0.001032$	<p>Status: <b>PASS</b> Ratio: <b>0.170</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> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;"><math>S_m = 4580.4 \text{ in}^3</math></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> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 48.018 \text{ kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(48.018 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.77415$	<p>Status: <b>PASS</b>  Ratio: <b>0.770</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.26902 \text{ kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.26902 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.0043372$	<p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>