

# Your Project Calculations



Project Name: MTSOLAR\_E954D330D4JJ

S3D Model Link:

[https://platform.skyciv.com/structural?preload\\_name=MTSOLAR\\_E954D330D4JJ&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/9\\_2023](https://platform.skyciv.com/structural?preload_name=MTSOLAR_E954D330D4JJ&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023)

Public Model Link:

[https://platform.skyciv.com/structural-viewer?project\\_id=CGRPnb6JOsgamlykszWRMWseWHT266QEurhk276ffn6NXlTMMHhgk8LnYYOohclp](https://platform.skyciv.com/structural-viewer?project_id=CGRPnb6JOsgamlykszWRMWseWHT266QEurhk276ffn6NXlTMMHhgk8LnYYOohclp)

## Array Specification

<b>Product:</b>	Beam
<b>Unique ID:</b>	4P-22.5-8TOP-HD-72-L-5Hx14W-79K2
<b>Duty Classification:</b>	HD
<b>Module Width:</b>	42.00 in
<b>Module Length:</b>	74.00in
<b>Number of Rows:</b>	5
<b>Number of Columns:</b>	14
<b>Total Number of Modules:</b>	70
<b>Desired Tilt Angle:</b>	30
<b>Front Edge Clearance:</b>	8
<b>Total Array Height at Tilt:</b>	16.80 ft
<b>Total Frame Length:</b>	87.00 ft
<b>Frame Weight:</b>	4020 lbs
<b>Array Dimensions N/S:</b>	17.71 ft
<b>Array Dimensions E/W:</b>	87.50 ft
<b>Rail Length:</b>	212.50 in
<b>Rail Spacing:</b>	3.08 ft
<b>Rail Check:</b>	Not Checked

## Support Specifications

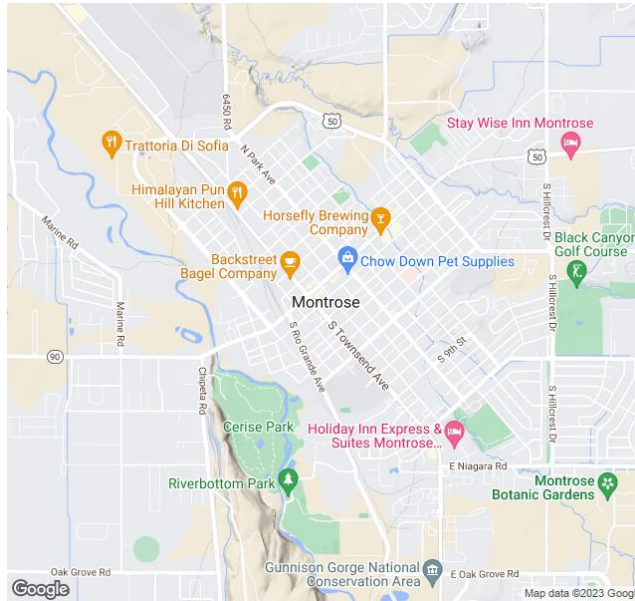
<b>Pole Size:</b>	8in Pipe Sch 40
<b>Pole Length above Grade:</b>	12.43 ft
<b>Number of Poles:</b>	4
<b>Pole Spacing:</b>	22.5 ft

## Foundation Specifications

<b>Foundation Type:</b>	Square
<b>Foundation Dimensions:</b>	48 x 48 in
<b>Foundation Depth (below grade):</b>	Pile 1: 6.75 ft Pile 2: 6.75 ft Pile 3: 6.75 ft Pile 4: 6.75 ft
<b>Foundation Volume:</b>	16.000 y <sup>3</sup>
<b>Foundation Result:</b>	PASSED
<b>Mount Twist:</b>	0.212178 kip

## Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	C
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	Montrose, CO 81401, USA
<b>Wind Speed:</b>	90 mph
<b>Snow Load:</b>	25 psf
<b>Design Uplift Pressure:</b>	Multiple pressures
<b>Design Downforce Pressure:</b>	Multiple pressures
<b>Design Snow Pressure:</b>	0.010996 ksf



### Design Disclaimer

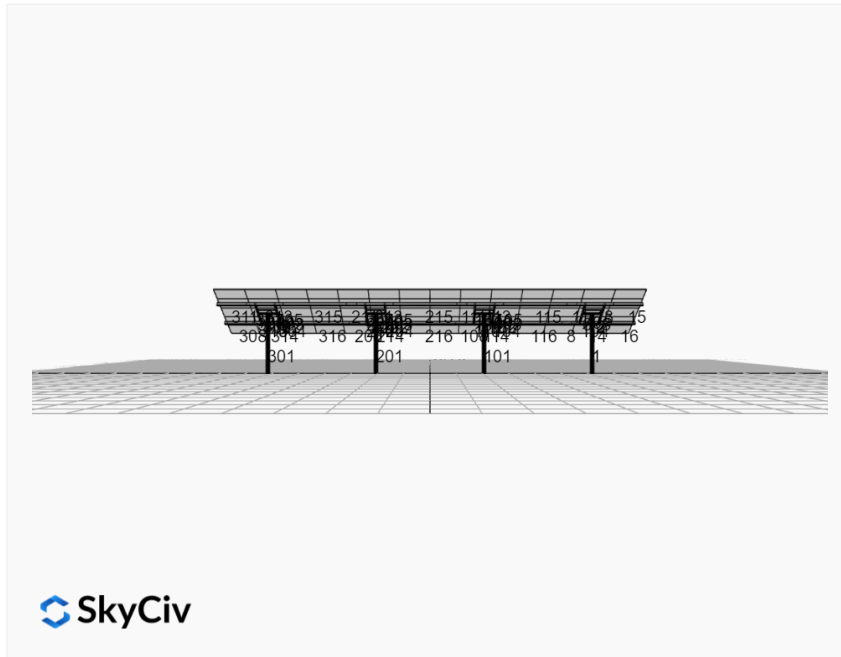
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

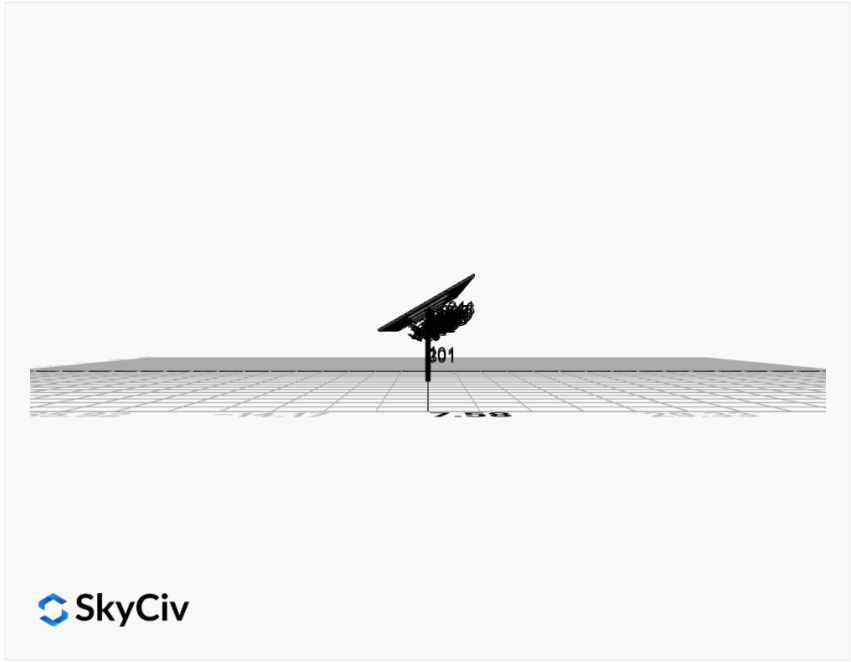
### AutoDesigner Input

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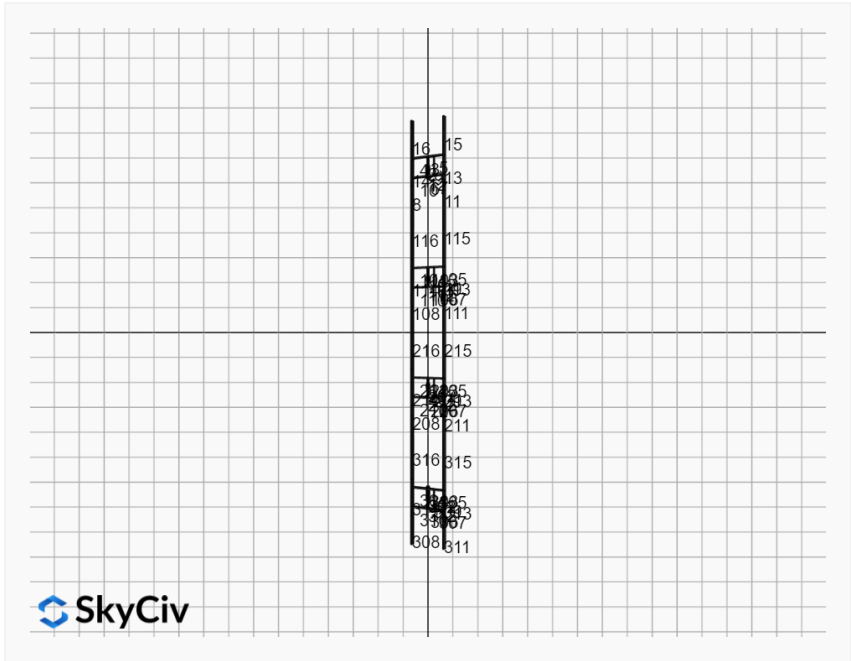
### Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only

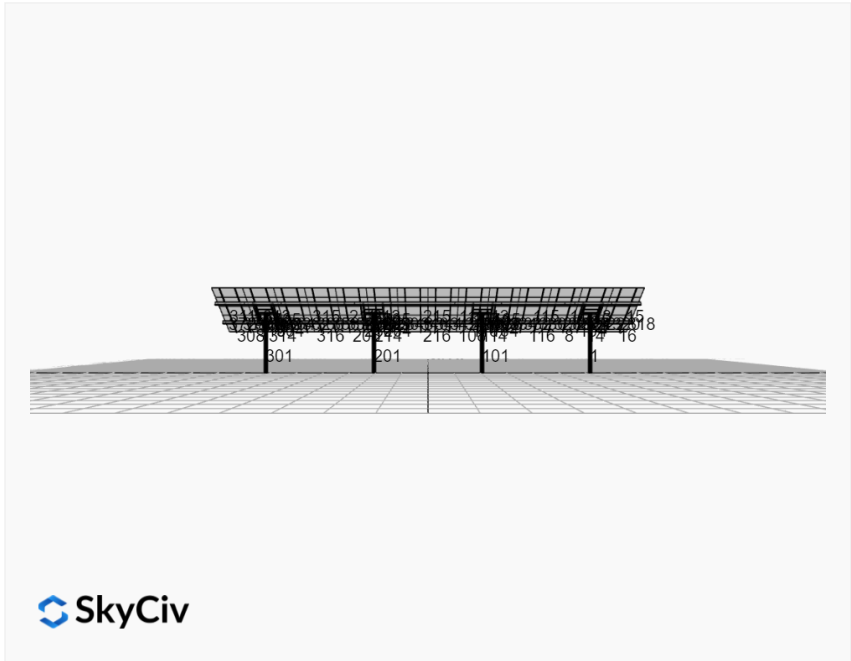
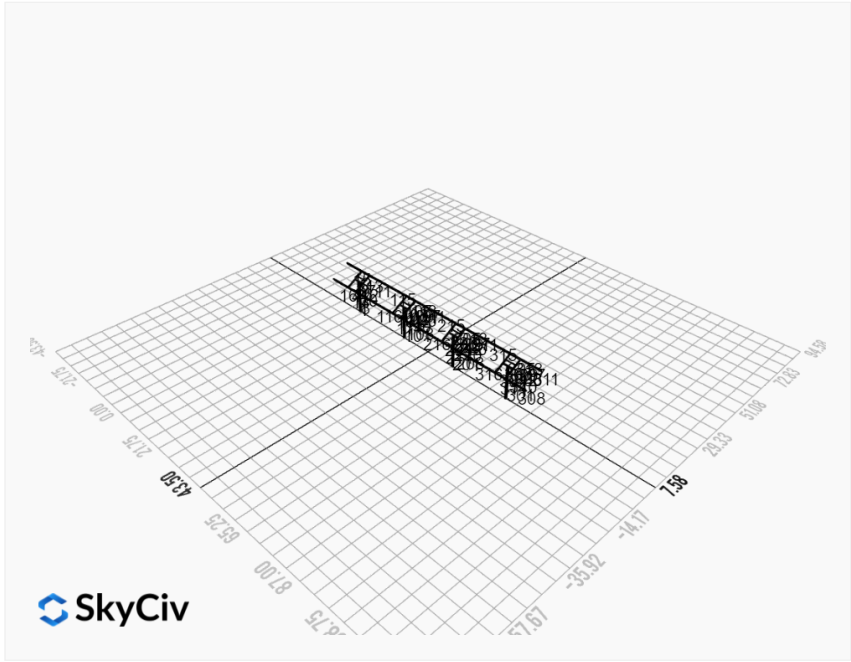




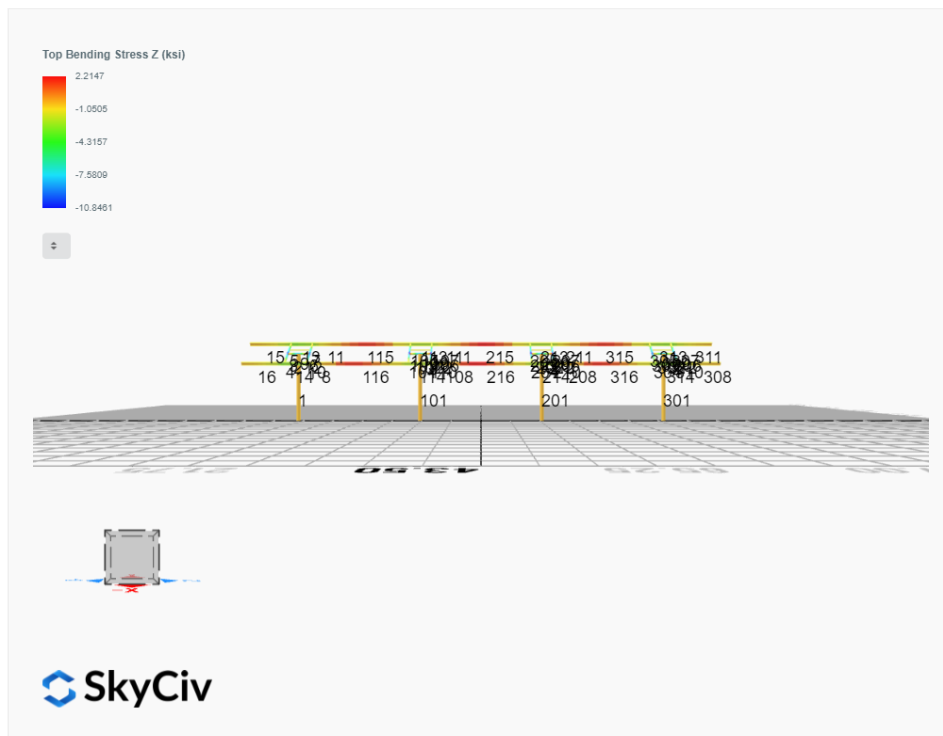
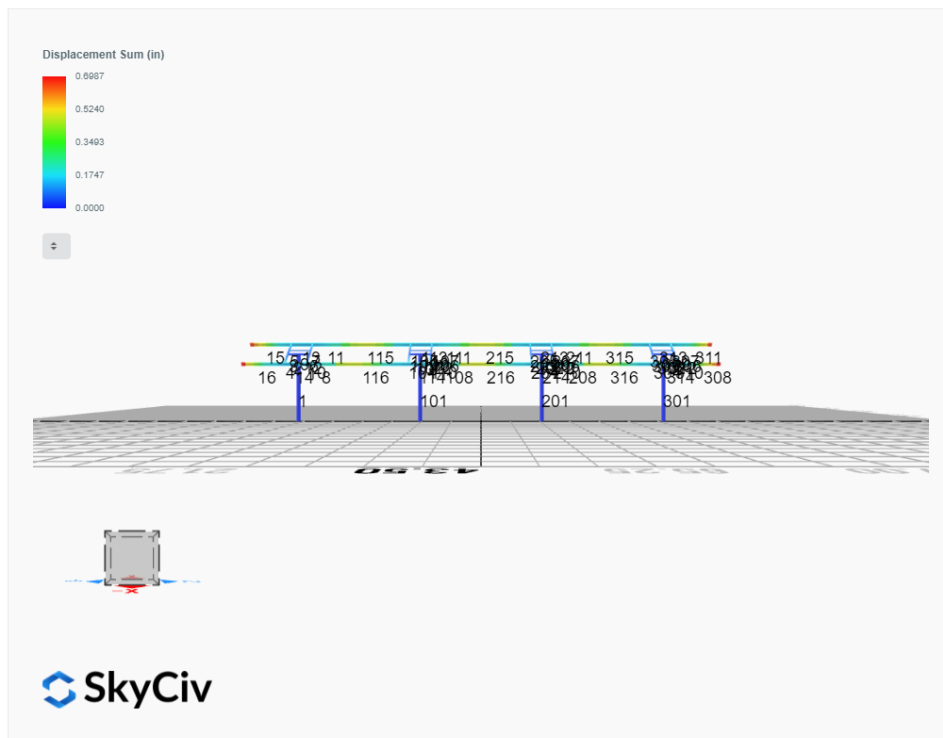
 SkyCiv

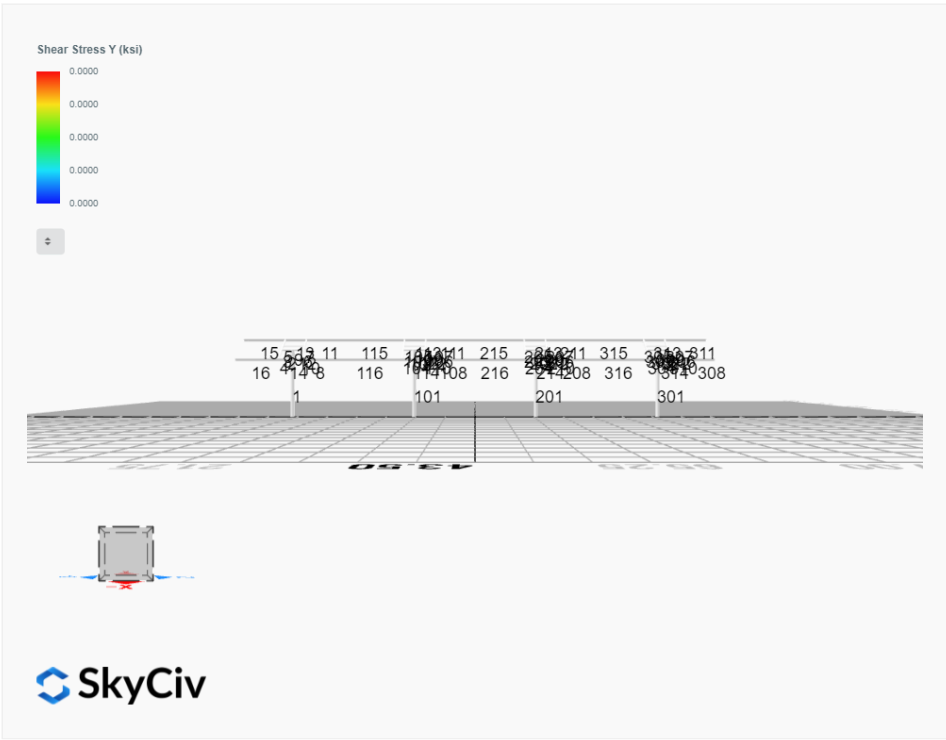
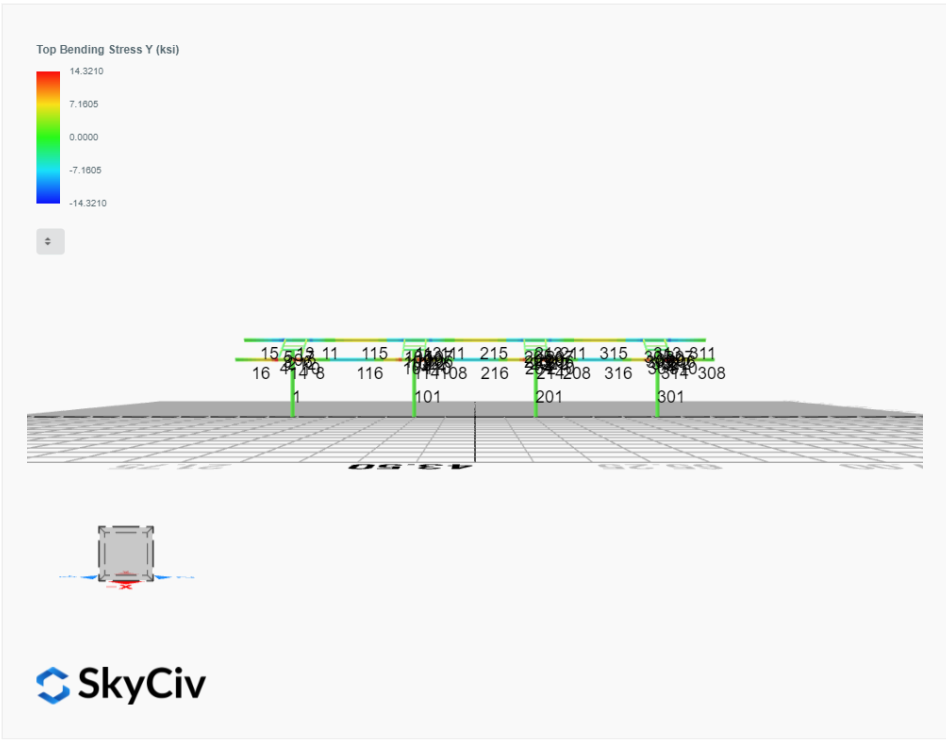


 SkyCiv



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







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

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0058	2.6998	-0.0112	-0.0389	0.0462	0.0972
ULS: 2. D + L	-0.0058	2.6998	-0.0112	-0.0389	0.0462	0.0972
ULS: 3. D + (S or Lr or R)	-0.0155	6.2595	-0.0297	-0.1030	0.1230	0.2266
ULS: 3. D + (S or Lr or R)	-0.0058	2.6998	-0.0112	-0.0389	0.0462	0.0972
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0131	5.3696	-0.0251	-0.0869	0.1038	0.1942
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0058	2.6998	-0.0112	-0.0389	0.0462	0.0972
ULS: 5b. D + 0.7E	-0.0058	2.6998	-0.0112	-0.0389	0.0462	0.0972
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0131	5.3696	-0.0251	-0.0869	0.1038	0.1942
ULS: 8. 0.6D + 0.7E	-0.0035	1.6199	-0.0067	-0.0233	0.0277	0.0583
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3504	6.7487	-0.0312	-0.1127	0.0880	29.9804
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3504	6.7487	-0.0312	-0.1127	0.0880	29.9804
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0030	-0.7702	0.0067	0.0269	0.0080	-24.3938
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6720	-0.1938	-0.0000	0.0025	0.0260	-28.5791
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7715	8.4062	-0.0401	-0.1423	0.1351	22.6066
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7715	8.4062	-0.0401	-0.1423	0.1351	22.6066
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4936	2.7671	-0.0116	-0.0376	0.0751	-18.1740
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2453	3.1993	-0.0167	-0.0559	0.0886	-21.3130
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7643	5.7365	-0.0262	-0.0942	0.0775	22.5096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7643	5.7365	-0.0262	-0.0942	0.0775	22.5096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5008	0.0973	0.0022	0.0104	0.0176	-18.2710
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2525	0.5296	-0.0028	-0.0078	0.0310	-21.4100
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3481	5.6688	-0.0268	-0.0972	0.0695	29.9415
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3481	5.6688	-0.0268	-0.0972	0.0695	29.9415
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0054	-1.8501	0.0112	0.0424	-0.0105	-24.4327
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6743	-1.2738	0.0045	0.0180	0.0075	-28.6180

### 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	12.3095
Shear X	-3.9202
Shear Z	-0.0597
Moment X	-0.2107
Moment Y (Twist)	0.2121
Moment Z	50.9963

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.4062
Shear X	-2.3504
Shear Z	-0.0401
Moment X	-0.1423
Moment Y (Twist)	0.1351
Moment Z	29.9804

## 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	0.0058	2.8293	0.0037	0.0139	-0.0092	-0.0402
ULS: 2. D + L	0.0058	2.8293	0.0037	0.0139	-0.0092	-0.0402
ULS: 3. D + (S or Lr or R)	0.0155	6.6054	0.0098	0.0369	-0.0246	-0.1392
ULS: 3. D + (S or Lr or R)	0.0058	2.8293	0.0037	0.0139	-0.0092	-0.0402
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0131	5.6614	0.0083	0.0312	-0.0208	-0.1144
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0058	2.8293	0.0037	0.0139	-0.0092	-0.0402
ULS: 5b. D + 0.7E	0.0058	2.8293	0.0037	0.0139	-0.0092	-0.0402

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0131	5.6614	0.0083	0.0312	-0.0208	-0.1144
ULS: 8. 0.6D + 0.7E	0.0035	1.6976	0.0022	0.0083	-0.0055	-0.0241
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4512	7.0972	0.0210	0.0774	-0.0565	31.2505
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4512	7.0972	0.0210	0.0774	-0.0565	31.2505
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1127	-0.8293	-0.0106	-0.0382	0.0294	-25.6497
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7578	-0.2175	-0.0107	-0.0386	0.0314	-29.9657
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8297	8.8623	0.0213	0.0788	-0.0562	23.3536
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8297	8.8623	0.0213	0.0788	-0.0562	23.3536
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5932	2.9174	-0.0024	-0.0078	0.0083	-19.3216
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3270	3.3763	-0.0025	-0.0082	0.0097	-22.5585
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8370	6.0302	0.0167	0.0615	-0.0447	23.4278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8370	6.0302	0.0167	0.0615	-0.0447	23.4278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5860	0.0854	-0.0070	-0.0251	0.0198	-19.2473
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3198	0.5442	-0.0071	-0.0255	0.0212	-22.4843
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4536	5.9655	0.0195	0.0718	-0.0528	31.2666
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4536	5.9655	0.0195	0.0718	-0.0528	31.2666
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1104	-1.9610	-0.0120	-0.0437	0.0331	-25.6336
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7555	-1.3492	-0.0122	-0.0441	0.0351	-29.9496

### 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	12.9933
Shear X	-4.0951
Shear Z	0.0369
Moment X	0.1361
Moment Y (Twist)	0.0991
Moment Z	53.1354

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.8623
Shear X	-2.4536
Shear Z	0.0213
Moment X	0.0788
Moment Y (Twist)	0.0565
Moment Z	31.2666

### 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	0.0058	2.8293	-0.0037	-0.0139	0.0092	-0.0402
ULS: 2. D + L	0.0058	2.8293	-0.0037	-0.0139	0.0092	-0.0402
ULS: 3. D + (S or Lr or R)	0.0155	6.6054	-0.0098	-0.0369	0.0246	-0.1392
ULS: 3. D + (S or Lr or R)	0.0058	2.8293	-0.0037	-0.0139	0.0092	-0.0402
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0131	5.6614	-0.0083	-0.0311	0.0208	-0.1144
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0058	2.8293	-0.0037	-0.0139	0.0092	-0.0402
ULS: 5b. D + 0.7E	0.0058	2.8293	-0.0037	-0.0139	0.0092	-0.0402
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0131	5.6614	-0.0083	-0.0311	0.0208	-0.1144
ULS: 8. 0.6D + 0.7E	0.0035	1.6976	-0.0022	-0.0083	0.0055	-0.0241
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4512	7.0972	-0.0210	-0.0774	0.0565	31.2505
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4512	7.0972	-0.0210	-0.0774	0.0565	31.2505
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1127	-0.8293	0.0106	0.0382	-0.0294	-25.6497
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7578	-0.2175	0.0107	0.0386	-0.0314	-29.9657
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8297	8.8623	-0.0213	-0.0788	0.0562	23.3536
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8297	8.8623	-0.0213	-0.0788	0.0562	23.3536
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5932	2.9174	0.0024	0.0079	-0.0083	-19.3216
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3270	3.3763	0.0025	0.0082	-0.0097	-22.5585

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8370	6.0302	-0.0167	-0.0615	0.0447	23.4278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8370	6.0302	-0.0167	-0.0615	0.0447	23.4278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5860	0.0854	0.0070	0.0252	-0.0198	-19.2473
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3198	0.5442	0.0071	0.0255	-0.0212	-22.4843
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4536	5.9655	-0.0195	-0.0718	0.0528	31.2666
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4536	5.9655	-0.0195	-0.0718	0.0528	31.2666
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1104	-1.9610	0.0120	0.0437	-0.0331	-25.6336
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7555	-1.3492	0.0122	0.0441	-0.0351	-29.9496

#### 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	12.9933
Shear X	-4.0951
Shear Z	-0.0369
Moment X	-0.1360
Moment Y (Twist)	0.0990
Moment Z	53.1354

#### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.8623
Shear X	-2.4536
Shear Z	-0.0213
Moment X	-0.0788
Moment Y (Twist)	0.0565
Moment Z	31.2666

#### 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	-0.0058	2.6998	0.0112	0.0389	-0.0463	0.0972
ULS: 2. D + L	-0.0058	2.6998	0.0112	0.0389	-0.0463	0.0972
ULS: 3. D + (S or Lr or R)	-0.0155	6.2595	0.0297	0.1030	-0.1230	0.2266
ULS: 3. D + (S or Lr or R)	-0.0058	2.6998	0.0112	0.0389	-0.0463	0.0972
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0131	5.3696	0.0251	0.0870	-0.1038	0.1942
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0058	2.6998	0.0112	0.0389	-0.0463	0.0972
ULS: 5b. D + 0.7E	-0.0058	2.6998	0.0112	0.0389	-0.0463	0.0972
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0131	5.3696	0.0251	0.0870	-0.1038	0.1942
ULS: 8. 0.6D + 0.7E	-0.0035	1.6199	0.0067	0.0233	-0.0278	0.0583
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3504	6.7487	0.0312	0.1127	-0.0880	29.9804
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3504	6.7487	0.0312	0.1127	-0.0880	29.9804
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0030	-0.7702	-0.0067	-0.0269	-0.0080	-24.3938
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6720	-0.1938	0.0000	-0.0025	-0.0260	-28.5791
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7715	8.4062	0.0401	0.1424	-0.1351	22.6066
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7715	8.4062	0.0401	0.1424	-0.1351	22.6066
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4936	2.7671	0.0116	0.0377	-0.0751	-18.1740
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2453	3.1993	0.0167	0.0560	-0.0886	-21.3131
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7643	5.7365	0.0262	0.0943	-0.0775	22.5096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7643	5.7365	0.0262	0.0943	-0.0775	22.5096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5008	0.0973	-0.0022	-0.0104	-0.0176	-18.2710
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2525	0.5296	0.0028	0.0079	-0.0310	-21.4100
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3481	5.6688	0.0268	0.0972	-0.0695	29.9415
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3481	5.6688	0.0268	0.0972	-0.0695	29.9415
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0054	-1.8501	-0.0112	-0.0424	0.0105	-24.4327
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6743	-1.2738	-0.0045	-0.0180	-0.0075	-28.6180

#### 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	12.3096
Shear X	-3.9202
Shear Z	0.0597
Moment X	0.2110
Moment Y (Twist)	0.2122
Moment Z	50.9967

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

Result	Value (kip, kip-ft)
Axial	8.4062
Shear X	-2.3504
Shear Z	0.0401
Moment X	0.1424
Moment Y (Twist)	0.1351
Moment Z	29.9804

## Project Details

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

User Name: sales@mtsolar.us  
 Project Name: MTSOLAR\_E954D330D4JJ  
 Unit System: imperial



## Design Input Information

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

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

Section Dimensions							

ID	Name	d (in)	t <sub>w</sub> (in)				
2	2in Pipe Sch 80	2.38	0.22				
5	4in Pipe Sch 80	4.50	0.34				
9	8in Pipe Sch 40	8.63	0.32				

ID	Name	d (in)	b (in)	t <sub>w</sub> (in)	t <sub>b</sub> (in)	r (in)	
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17	

ID	Name	d (in)	t <sub>w</sub> (in)	b <sub>t</sub> (in)	b <sub>b</sub> (in)	t <sub>t</sub> (in)	t <sub>b</sub> (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

Section Properties								
ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	I <sub>yp</sub> (in <sup>4</sup> )	I <sub>zp</sub> (in <sup>4</sup> )	I <sub>w</sub> (in <sup>6</sup> )	S <sub>yp</sub> (in <sup>3</sup> )	S <sub>zp</sub> (in <sup>3</sup> )
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85

9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K <sub>z</sub> L (ft)	K <sub>y</sub> L (ft)	L <sub>b</sub> (ft)	C <sub>b</sub>	L S T	L S C	L D
1	9	26.10	26.10	12.43	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
4	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.76,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.55	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	2.20,2.20,2.20,2.19,2.20,2.20,2.20,2.20,2.21,2.01,2.20,2.20,2.20,1.62,2.20,2.20,2.19,2.16,2.20,2.20,2.21,2.05,2.20,2.20,2.20,1.65	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.51	300	200	1
11	19	1.33	1.33	2.05	2.21,2.21,2.21,2.21,2.21,2.21,2.14,2.14,2.02,2.01,2.13,2.13,2.08,2.05,2.17,2.17,2.22,2.25,2.15,2.15,1.97,1.99,2.13,2.13,2.09,2.06	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.09,1.08,1.08,1.07,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.07,1.10,1.08,1.08,1.07,1.08	300	200	1
14	19	4.88	4.00	7.50	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.22,1.08,1.08,1.08,4.19,1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.16,1.08,1.08,1.08,1.05	300	200	1
15	19	12.60	12.60	6.00	2.33,2.33	300	200	1
16	19	12.60	12.60	6.00	2.33,2.33	300	200	1
101	9	26.10	26.10	12.43	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.53	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1





103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.60	6.12	40.24	43.62
114	133.20	104.94	23.60	6.12	40.24	43.62
115	133.20	46.28	12.46	6.12	40.24	43.62
116	133.20	46.28	12.35	6.12	40.24	43.62
201	377.97	164.67	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	23.60	6.12	40.24	43.62
214	133.20	104.94	23.60	6.12	40.24	43.62
215	133.20	46.28	12.46	6.12	40.24	43.62
216	133.20	46.28	12.02	6.12	40.24	43.62
301	377.97	164.67	83.29	83.29	113.39	113.39
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	20.65	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	20.65	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	104.94	24.52	6.12	40.24	43.62
314	133.20	104.94	24.06	6.12	40.24	43.62
315	133.20	46.28	12.67	6.12	40.24	43.62
316	133.20	46.28	12.02	6.12	40.24	43.62

## Design Ratio

Member ID	P	M <sub>z</sub>	M <sub>y</sub>	V <sub>y</sub>	V <sub>z</sub>	(P,M <sub>z</sub> ,M <sub>y</sub> )	Worst LC	KL/r	δ	Status
1	0.075	0.612	0.006	0.035	0.001	0.650	#13	0.533	Not Required	Pass
2	0.005	0.470	0.194	0.101	0.034	0.657	#13	0.035	Not Required	Pass
3	0.009	0.705	0.048	0.071	0.004	0.731	#13	0.045	Not Required	Pass

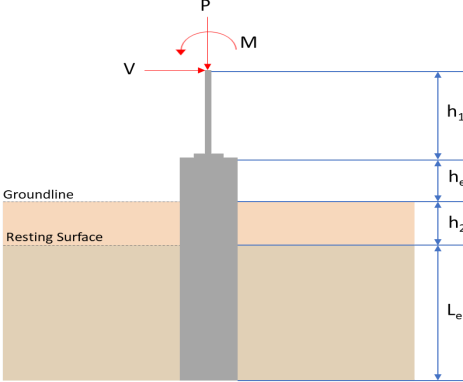
4	0.009	0.703	0.196	0.071	0.039	0.788	#21	0.080	Not Required	Pass
5	0.009	0.437	0.207	0.070	0.052	0.474	#21	0.074	Not Required	Pass
6	0.009	0.687	0.050	0.069	0.003	0.711	#13	0.045	Not Required	Pass
7	0.009	0.427	0.203	0.068	0.053	0.466	#21	0.074	Not Required	Pass
8	0.000	0.088	0.209	0.052	0.017	0.287	#21	0.095	Not Required	Pass
9	0.022	0.075	0.050	0.001	0.000	0.130	#21	0.204	Not Required	Pass
10	0.009	0.680	0.197	0.068	0.041	0.779	#21	0.080	Not Required	Pass
11	0.000	0.091	0.212	0.052	0.017	0.290	#21	0.095	Not Required	Pass
12	0.005	0.446	0.186	0.099	0.032	0.627	#13	0.035	Not Required	Pass
13	0.009	0.344	0.480	0.064	0.021	0.797	#21	0.286	Not Required	Pass
14	0.009	0.347	0.480	0.064	0.021	0.797	#21	0.190	Not Required	Pass
15	0.000	0.149	0.288	0.041	0.013	0.431	#21	Not Required	Not Required	Pass
16	0.000	0.149	0.288	0.041	0.013	0.431	#21	Not Required	Not Required	Pass
101	0.079	0.638	0.004	0.036	0.000	0.677	#13	0.533	Not Required	Pass
102	0.004	0.474	0.193	0.105	0.034	0.657	#13	0.035	Not Required	Pass
103	0.010	0.725	0.048	0.072	0.001	0.753	#13	0.045	Not Required	Pass
104	0.010	0.724	0.189	0.073	0.039	0.818	#21	0.080	Not Required	Pass
105	0.010	0.449	0.195	0.072	0.050	0.486	#21	0.074	Not Required	Pass
106	0.010	0.740	0.049	0.074	0.002	0.769	#13	0.045	Not Required	Pass
107	0.010	0.459	0.195	0.074	0.050	0.494	#21	0.074	Not Required	Pass
108	0.000	0.068	0.204	0.051	0.017	0.269	#21	0.095	Not Required	Pass
109	0.019	0.071	0.049	0.001	0.000	0.123	#21	0.204	Not Required	Pass
110	0.010	0.737	0.186	0.074	0.039	0.823	#21	0.080	Not Required	Pass
111	0.000	0.066	0.207	0.051	0.017	0.272	#21	0.095	Not Required	Pass
112	0.004	0.486	0.198	0.106	0.035	0.676	#13	0.035	Not Required	Pass
113	0.009	0.278	0.443	0.063	0.021	0.694	#21	0.286	Not Required	Pass
114	0.008	0.287	0.441	0.063	0.021	0.693	#21	0.286	Not Required	Pass
115	0.000	0.396	0.240	0.050	0.017	0.621	#21	0.601	Not Required	Pass
116	0.000	0.399	0.242	0.050	0.017	0.624	#21	0.601	Not Required	Pass
201	0.079	0.638	0.004	0.036	0.000	0.677	#13	0.533	Not Required	Pass
202	0.004	0.486	0.198	0.106	0.035	0.676	#13	0.035	Not Required	Pass
203	0.010	0.740	0.049	0.074	0.002	0.769	#13	0.045	Not Required	Pass
204	0.010	0.737	0.186	0.074	0.039	0.823	#21	0.080	Not Required	Pass
205	0.010	0.459	0.195	0.074	0.050	0.494	#21	0.074	Not Required	Pass
206	0.010	0.725	0.048	0.072	0.001	0.753	#13	0.045	Not Required	Pass
207	0.010	0.449	0.195	0.072	0.050	0.486	#21	0.074	Not Required	Pass
208	0.000	0.069	0.206	0.050	0.017	0.273	#21	0.095	Not Required	Pass
209	0.019	0.071	0.049	0.001	0.000	0.123	#21	0.204	Not Required	Pass
210	0.010	0.724	0.189	0.073	0.039	0.818	#21	0.080	Not Required	Pass
211	0.000	0.066	0.209	0.050	0.017	0.274	#21	0.095	Not Required	Pass
212	0.004	0.474	0.193	0.105	0.034	0.657	#13	0.035	Not Required	Pass
213	0.009	0.278	0.443	0.063	0.021	0.694	#21	0.286	Not Required	Pass
214	0.008	0.287	0.441	0.063	0.021	0.693	#21	0.286	Not Required	Pass
215	0.001	0.431	0.240	0.051	0.017	0.651	#21	0.601	Not Required	Pass
216	0.000	0.430	0.242	0.051	0.017	0.653	#21	0.601	Not Required	Pass
301	0.075	0.612	0.006	0.035	0.001	0.650	#13	0.533	Not Required	Pass
302	0.005	0.446	0.186	0.099	0.032	0.627	#13	0.035	Not Required	Pass
303	0.009	0.687	0.050	0.069	0.003	0.711	#13	0.045	Not Required	Pass
304	0.009	0.680	0.197	0.068	0.041	0.779	#21	0.080	Not Required	Pass
305	0.009	0.427	0.203	0.068	0.053	0.466	#21	0.074	Not Required	Pass
306	0.009	0.705	0.048	0.071	0.004	0.731	#13	0.045	Not Required	Pass
307	0.009	0.437	0.207	0.070	0.052	0.474	#21	0.074	Not Required	Pass
308	0.000	0.149	0.288	0.041	0.013	0.431	#21	Not Required	Not Required	Pass
309	0.022	0.075	0.050	0.001	0.000	0.130	#21	0.204	Not Required	Pass

309	0.022	0.073	0.030	0.001	0.000	0.130	#21	0.204	Not Required	Pass
310	0.009	0.703	0.196	0.071	0.039	0.788	#21	0.080	Not Required	Pass
311	0.000	0.149	0.288	0.041	0.013	0.431	#21	Not Required	Not Required	Pass
312	0.005	0.470	0.194	0.101	0.034	0.657	#13	0.035	Not Required	Pass
313	0.009	0.344	0.480	0.064	0.021	0.797	#21	0.190	Not Required	Pass
314	0.009	0.347	0.480	0.064	0.021	0.797	#21	0.286	Not Required	Pass
315	0.000	0.395	0.240	0.052	0.017	0.616	#21	0.601	Not Required	Pass
316	0.000	0.393	0.242	0.052	0.017	0.618	#21	0.601	Not Required	Pass

## Definitions

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



REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.75</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 resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.406</td> <td>12.310</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.350</td> <td>-3.920</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.040</td> <td>-0.060</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.142</td> <td>-0.211</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>29.980</td> <td>50.996</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.406	12.310	$V_x$ (kip)	-2.350	-3.920	$V_z$ (kip)	-0.040	-0.060	$M_x$ (kipft)	-0.142	-0.211	$M_z$ (kipft)	29.980	50.996	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.35 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.3742 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(29.98 \text{ kipft}) + ((-2.35 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.7739 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.2317 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.04 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0063694 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.142 \text{ kipft}) + ((-0.04 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.022611 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.1141 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2317 \text{ ft}), (1.1141 \text{ ft})]$$

$$L_{e,req} = 6.232 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.232 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.92326$$

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

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(8.406 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.52538 \text{ kip/ft}^2$$

$$q = 0.52538 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$Ratio = \frac{(0.52538 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.26269$$

Status: **PASS**  
Ratio: **0.260**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.3742 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.7739 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.7739 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (4.7739 \text{ kipft/ft})) + (4 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6467 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.7739 \text{ kipft/ft})) + (3 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (4.7739 \text{ kipft/ft})) + (2 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.23557 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.7739 \text{ kipft/ft})) + ((-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.92469 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6467 \text{ ft})}{2}$$

$$p_a = 0.3485 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.23557 \text{ kip/ft}^2)}{(0.3485 \text{ kip/ft}^2)}$$

$$Ratio = 0.67596$$

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

Status: **PASS**  
Ratio: **0.680**

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.92469 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.91328$$

Status: **PASS**  
Ratio: **0.910**

**Considering z-direction:**

$H_o = -0.0063694 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.022611 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.022611 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.022611 \text{ kipft/ft})) + (4 \times (-0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8144 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.022611 \text{ kipft/ft})) + (3 \times (-0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.022611 \text{ kipft/ft})) + (2 \times (-0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = -0.0013465 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.022611 \text{ kipft/ft})) + ((-0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.00029357 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8144 \text{ ft})}{2}$$

$$p_a = 0.36108 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0013465 \text{ kip/ft}^2)}{(0.36108 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.0037292$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

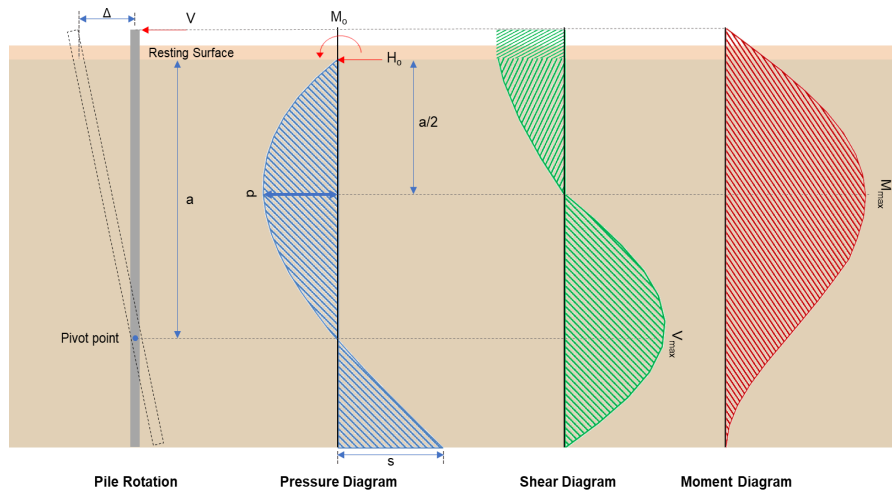
$$\text{Ratio} = \frac{s}{p_s}$$

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

$$\text{Ratio} = \frac{(0.00029357 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.00028995$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.92 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.6242 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(50.996 \text{ kipft}) + ((-3.92 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.1204 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.1204 \text{ kipft/ft})}{(-0.6242 \text{ kip/ft})}$$

$$E = 13.009 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.1204 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.6242 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (8.1204 \text{ kipft/ft})) + (4 \times (-0.6242 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6446 \text{ ft}$$

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

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

$$V_{max} = ((-0.6242 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6446 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6446 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.163 \text{ kip}$$

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

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

$$M_{max} = ((-0.6242 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(13.009 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 32.767 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.06 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0095541 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.211 \text{ kipft}) + ((-0.06 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.033599 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.033599 \text{ kipft/ft})}{(-0.0095541 \text{ kip/ft})}$$

$$E = 3.5167 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.033599 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.0095541 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.033599 \text{ kipft/ft})) + (4 \times (-0.0095541 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8157 \text{ ft}$$

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

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

$$V_{max} = ((-0.0095541 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8157 \text{ ft})}{(6.75 \text{ ft})} \right)^2 + \left[ 4 \times \left( \frac{3 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8157 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right] \right]$$

$$V_{max} = 0.060678 \text{ kip}$$

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

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

$$M_{max} = ((-0.0095541 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(3.5167 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.18177 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.31 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.187 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.187 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2  $\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.31 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0046016$$

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

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

**Parameters:**

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

$$d = 0.80 D$$

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

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

22.5.5.1.3  $\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.31 \text{ kip} \rightarrow 12310 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12310 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.13 \text{ kip}$$

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

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

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

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

$V_c$  - Governing shear strength of concrete

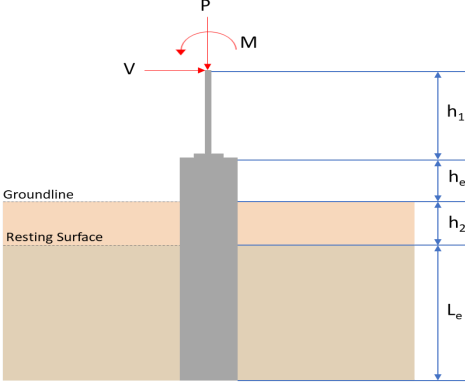
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.13 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.13 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{ytks} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.13 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.16 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.163 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.163 \text{ kip})}{(111.16 \text{ kip})}$ $\text{Ratio} = 0.091423$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.060678 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.060678 \text{ kip})}{(111.16 \text{ kip})}$ $\text{Ratio} = 0.00054585$	<p>Status: <b>PASS</b>  Ratio: <b>0.090</b></p> <p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 32.767 \text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(32.767 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.13128$	<p>Status: <b>PASS</b>  Ratio: <b>0.130</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.18177 \text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.18177 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.00072823$	<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: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.75</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 resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.862</td> <td>12.993</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.454</td> <td>-4.095</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.021</td> <td>0.037</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.079</td> <td>0.136</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>31.267</td> <td>53.135</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.862	12.993	$V_x$ (kip)	-2.454	-4.095	$V_z$ (kip)	0.021	0.037	$M_x$ (kipft)	0.079	0.136	$M_z$ (kipft)	31.267	53.135	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.454 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.39076 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(31.267 \text{ kipft}) + ((-2.454 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9788 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.3039 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.021 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0033439 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.079 \text{ kipft}) + ((0.021 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01258 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.0687 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.3039 \text{ ft}), (1.0687 \text{ ft})]$$

$$L_{e,req} = 6.304 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.304 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.93393$$

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

**End-bearing Capacity (ASD)**

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.862 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.553875 \text{ kip/ft}^2$$

$$q = 0.00001 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.55387 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.27694$$

Status: **PASS**  
Ratio: **0.280**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.39076 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.9788 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.9788 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (4.9788 \text{ kipft/ft})) + (4 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6468 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.9788 \text{ kipft/ft})) + (3 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (4.9788 \text{ kipft/ft})) + (2 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.24545 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.9788 \text{ kipft/ft})) + ((-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.96395 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6468 \text{ ft})}{2}$$

$$p_a = 0.34851 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.24545 \text{ kip/ft}^2)}{(0.34851 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.70427$$

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

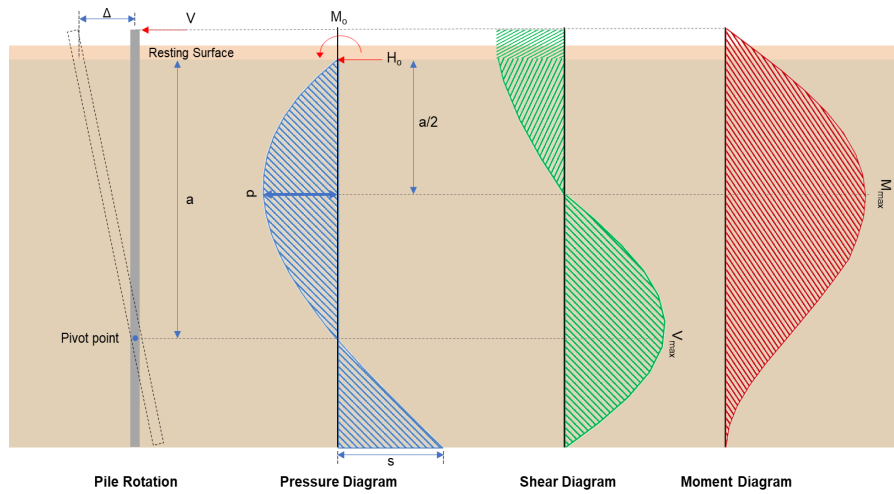
Status: **PASS**  
Ratio: **0.700**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$ $p_s = 1.0125 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.96395 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.95205$	<p>Status: <b>PASS</b> Ratio: <b>0.950</b></p>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = 0.0033439 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.01258 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.01258 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.01258 \text{ kipft/ft})) + (4 \times (0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))}$ $a = 4.8064 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.01258 \text{ kipft/ft})) + (3 \times (0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.01258 \text{ kipft/ft})) + (2 \times (0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$ $p = 0.002767 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.01258 \text{ kipft/ft})) + ((0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$ $s = 0.0062855 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.8064 \text{ ft})}{2}$ $p_a = 0.36048 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.002767 \text{ kip/ft}^2)}{(0.36048 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.0076758$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (6.75 \text{ ft})$ $p_s = 1.0125 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	<p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>

$$Ratio = \frac{(0.0062855 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.006208$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-4.095 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.65207 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(53.135 \text{ kipft}) + ((-4.095 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.461 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.461 \text{ kipft/ft})}{(-0.65207 \text{ kip/ft})}$$

$$E = 12.976 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.461 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.65207 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (8.461 \text{ kipft/ft})) + (4 \times (-0.65207 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6448 \text{ ft}$$

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

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

$$V_{max} = ((-0.65207 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6448 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6448 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.594 \text{ kip}$$

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

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

$$M_{max} = ((-0.65207 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(12.976 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 34.153 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.037 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0058917 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.136 \text{ kipft}) + ((0.037 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.021656 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.021656 \text{ kipft/ft})}{(0.0058917 \text{ kip/ft})}$$

$$E = 3.6757 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.021656 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.0058917 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.021656 \text{ kipft/ft})) + (4 \times (0.0058917 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8096 \text{ ft}$$

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

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

$$V_{max} = ((0.0058917 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8096 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8096 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.03839 \text{ kip}$$

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

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

$$M_{max} = ((0.0058917 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(3.6757 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11536 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.993 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.164 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.164 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.993 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0048569$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.993 \text{ kip} \rightarrow 12993 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12993 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.22 \text{ kip}$$

22.5.5.1.2

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

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

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

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

$V_c$  - Governing shear strength of concrete

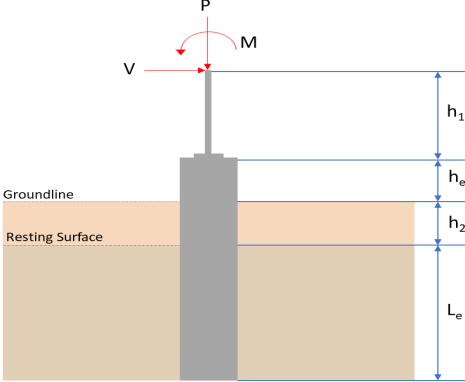
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.22 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.22 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.22 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.22 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.594 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.594 \text{ kip})}{(111.22 \text{ kip})}$ $\text{Ratio} = 0.095247$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.03839 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.03839 \text{ kip})}{(111.22 \text{ kip})}$ $\text{Ratio} = 0.00034517$	<p>Status: <b>PASS</b>  Ratio: <b>0.100</b></p> <p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 34.153 \text{ kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(34.153 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.13683$	<p>Status: <b>PASS</b>  Ratio: <b>0.140</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.11536 \text{ kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.11536 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.00046219$	<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: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.75</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 resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.862</td> <td>12.993</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.454</td> <td>-4.095</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.021</td> <td>-0.037</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.079</td> <td>-0.136</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>31.267</td> <td>53.135</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.862	12.993	$V_x$ (kip)	-2.454	-4.095	$V_z$ (kip)	-0.021	-0.037	$M_x$ (kipft)	-0.079	-0.136	$M_z$ (kipft)	31.267	53.135	
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$M_z$ (kipft)	31.267	53.135																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.454 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.39076 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(31.267 \text{ kipft}) + ((-2.454 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9788 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.3039 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.021 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0033439 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.079 \text{ kipft}) + ((-0.021 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01258 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.93558 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.3039 \text{ ft}), (0.93558 \text{ ft})]$$

$$L_{e,req} = 6.304 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.304 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.93393$$

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

**End-bearing Capacity (ASD)**

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.862 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.553875 \text{ kip/ft}^2$$

$$q = 0.00001 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.55387 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.27694$$

Status: **PASS**  
Ratio: **0.280**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.39076 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.9788 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.9788 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (4.9788 \text{ kipft/ft})) + (4 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6468 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.9788 \text{ kipft/ft})) + (3 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (4.9788 \text{ kipft/ft})) + (2 \times (-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.24545 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.9788 \text{ kipft/ft})) + ((-0.39076 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.96395 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6468 \text{ ft})}{2}$$

$$p_a = 0.34851 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.24545 \text{ kip/ft}^2)}{(0.34851 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.70427$$

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

Status: **PASS**  
Ratio: **0.700**

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.96395 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.95205$$

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

**Considering z-direction:**

$H_o = -0.0033439 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.01258 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.01258 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.01258 \text{ kipft/ft})) + (4 \times (-0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8064 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.01258 \text{ kipft/ft})) + (3 \times (-0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.01258 \text{ kipft/ft})) + (2 \times (-0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = -0.0006728 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.01258 \text{ kipft/ft})) + ((-0.0033439 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.00034075 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8064 \text{ ft})}{2}$$

$$p_a = 0.36048 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0006728 \text{ kip/ft}^2)}{(0.36048 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.0018664$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

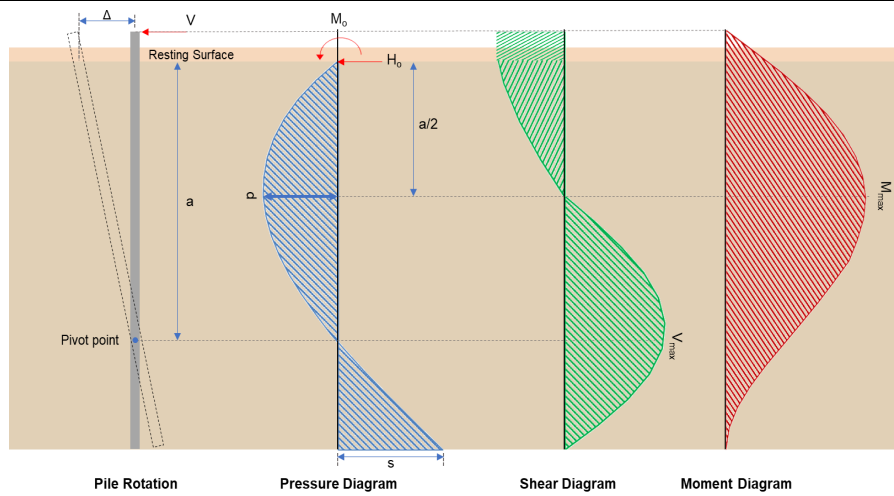
$$\text{Ratio} = \frac{s}{p_s}$$

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

$$\text{Ratio} = \frac{(0.00034075 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.00033654$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-4.095 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.65207 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(53.135 \text{ kipft}) + ((-4.095 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.461 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.461 \text{ kipft/ft})}{(-0.65207 \text{ kip/ft})}$$

$$E = 12.976 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.461 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.65207 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (8.461 \text{ kipft/ft})) + (4 \times (-0.65207 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6448 \text{ ft}$$

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

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

$$V_{max} = ((-0.65207 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6448 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6448 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.594 \text{ kip}$$

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

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

$$M_{max} = ((-0.65207 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(12.976 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.976 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6448 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 34.153 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.037 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0058917 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.136 \text{ kipft}) + ((-0.037 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.021656 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.021656 \text{ kipft/ft})}{(-0.0058917 \text{ kip/ft})}$$

$$E = 3.6757 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.021656 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.0058917 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.021656 \text{ kipft/ft})) + (4 \times (-0.0058917 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8096 \text{ ft}$$

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

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

$$V_{max} = ((-0.0058917 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8096 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8096 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.03839 \text{ kip}$$

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

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

$$M_{max} = ((-0.0058917 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(3.6757 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.6757 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8096 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.11536 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.993 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.164 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.164 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

25.7.2.2

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

25.7.2.1

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.993 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0048569$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.993 \text{ kip} \rightarrow 12993 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12993 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.22 \text{ kip}$$

22.5.5.1.2

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

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

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

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

$V_c$  - Governing shear strength of concrete

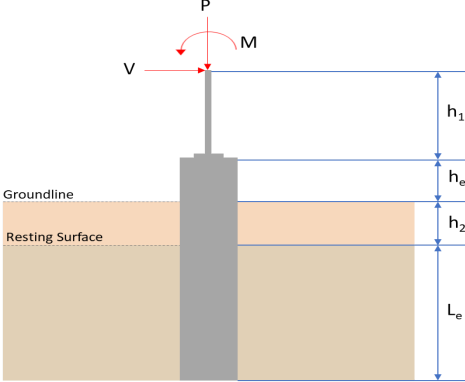
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.22 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.22 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.22 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.22 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.594 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.594 \text{ kip})}{(111.22 \text{ kip})}$ $\text{Ratio} = 0.095247$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.03839 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.03839 \text{ kip})}{(111.22 \text{ kip})}$ $\text{Ratio} = 0.00034517$	<p>Status: <b>PASS</b> Ratio: <b>0.100</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),          Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 34.153 \text{kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(34.153 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.13683$	<p>Status: <b>PASS</b>          Ratio: <b>0.140</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.11536 \text{kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.11536 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.00046219$	<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: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 6.75</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 resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>8.406</td> <td>12.310</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.350</td> <td>-3.920</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.040</td> <td>0.060</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.142</td> <td>0.211</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>29.980</td> <td>50.997</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	8.406	12.310	$V_x$ (kip)	-2.350	-3.920	$V_z$ (kip)	0.040	0.060	$M_x$ (kipft)	0.142	0.211	$M_z$ (kipft)	29.980	50.997	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.35 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.3742 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(29.98 \text{ kipft}) + ((-2.35 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.7739 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.2317 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.04 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0063694 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.142 \text{ kipft}) + ((0.04 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.022611 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.3227 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.2317 \text{ ft}), (1.3227 \text{ ft})]$$

$$L_{e,req} = 6.232 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.232 \text{ ft})}{(6.75 \text{ ft})}$$

$$\text{Ratio} = 0.92326$$

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

**End-bearing Capacity (ASD)**

$A$  - Pile cross-section area

$$A = b D$$

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

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

$q$  - End-bearing pressure

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

$$q = \frac{(8.406 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.52538 \text{ kip/ft}^2$$

$$q = 0.52538 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.52538 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.26269$$

Status: **PASS**  
Ratio: **0.260**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.6875$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.3742 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.7739 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.7739 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (4.7739 \text{ kipft/ft})) + (4 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6467 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.7739 \text{ kipft/ft})) + (3 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (4.7739 \text{ kipft/ft})) + (2 \times (-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.23557 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.7739 \text{ kipft/ft})) + ((-0.3742 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.92469 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.6467 \text{ ft})}{2}$$

$$p_a = 0.3485 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.23557 \text{ kip/ft}^2)}{(0.3485 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.67596$$

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

Status: **PASS**  
Ratio: **0.680**

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.92469 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.91328$$

Status: **PASS**  
Ratio: **0.910**

**Considering z-direction:**

$H_o = 0.0063694 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.022611 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.022611 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.022611 \text{ kipft/ft})) + (4 \times (0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8144 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.022611 \text{ kipft/ft})) + (3 \times (0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]^2}{(6.75 \text{ ft})^2 \times [(3 \times (0.022611 \text{ kipft/ft})) + (2 \times (0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]}$$

$$p = 0.0051525 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (0.022611 \text{ kipft/ft})) + ((0.0063694 \text{ kip/ft}) \times (6.75 \text{ ft}))]}{(6.75 \text{ ft})^2}$$

$$s = 0.011617 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8144 \text{ ft})}{2}$$

$$p_a = 0.36108 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0051525 \text{ kip/ft}^2)}{(0.36108 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.014269$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

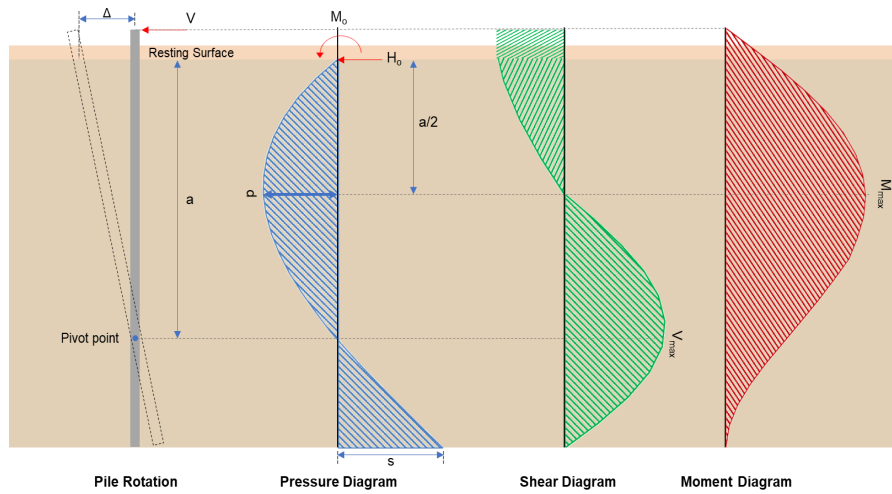
$$\text{Ratio} = \frac{s}{p_s}$$

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

$$Ratio = \frac{(0.011617 \text{ kip/ft}^2)}{(1.0125 \text{ kip/ft}^2)}$$

$$Ratio = 0.011474$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.92 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.6242 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(50.997 \text{ kipft}) + ((-3.92 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.1205 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.1205 \text{ kipft/ft})}{(-0.6242 \text{ kip/ft})}$$

$$E = 13.009 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.1205 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (-0.6242 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (8.1205 \text{ kipft/ft})) + (4 \times (-0.6242 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.6446 \text{ ft}$$

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

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

$$V_{max} = ((-0.6242 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6446 \text{ ft})}{(6.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6446 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.163 \text{ kip}$$

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

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

$$M_{max} = ((-0.6242 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(13.009 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (13.009 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.6446 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 32.768 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.06 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0095541 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.211 \text{ kipft}) + ((0.06 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.033599 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.033599 \text{ kipft/ft})}{(0.0095541 \text{ kip/ft})}$$

$$E = 3.5167 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.033599 \text{ kipft/ft}) \times (6.75 \text{ ft})) + (3 \times (0.0095541 \text{ kip/ft}) \times (6.75 \text{ ft})^2)}{(6 \times (0.033599 \text{ kipft/ft})) + (4 \times (0.0095541 \text{ kip/ft}) \times (6.75 \text{ ft}))}$$

$$a = 4.8157 \text{ ft}$$

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

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

$$V_{max} = ((0.0095541 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8157 \text{ ft})}{(6.75 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8157 \text{ ft})}{(6.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.060678 \text{ kip}$$

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

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

$$M_{max} = ((0.0095541 \text{ kip/ft}) \times (48 \text{ in}) \times (6.75 \text{ ft})) \times \left[ \left( \frac{(3.5167 \text{ ft})}{(6.75 \text{ ft})} + \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 3 \right) \times \left( \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (3.5167 \text{ ft})}{(6.75 \text{ ft})} + 2 \right) \times \left( \frac{(4.8157 \text{ ft})}{2 \times (6.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.18177 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 2.5 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.31 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.187 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.187 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.31 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0046016$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 12.31 \text{ kip} \rightarrow 12310 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12310 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.13 \text{ kip}$$

22.5.5.1.2

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

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

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

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

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.13 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.13 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 737.28 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{ytks} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.13 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.16 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.163 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.163 \text{ kip})}{(111.16 \text{ kip})}$ $\text{Ratio} = 0.091425$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.060678 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.060678 \text{ kip})}{(111.16 \text{ kip})}$ $\text{Ratio} = 0.00054585$	<p>Status: <b>PASS</b>  Ratio: <b>0.090</b></p> <p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),          Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ksi}} \times 18432.001 \text{in}^3$ $\phi M_{n,1} = 249.600 \text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ksi}) \times (18432 \text{in}^3)$ $\phi M_{n,2} = 2121.6 \text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(249.6 \text{kipft}), (2121.6 \text{kipft})]$ $\phi M_n = 249.6 \text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 32.768 \text{kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(32.768 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.13128$	<p>Status: <b>PASS</b>          Ratio: <b>0.130</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.18177 \text{kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.18177 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.00072823$	<p>Status: <b>PASS</b>          Ratio: <b>0.000</b></p>