

# Your Project Calculations



Project Name: Butch Tucker 2

S3D Model Link:

[https://platform.skyciv.com/structural?preload\\_name=Butch%20Tucker%202&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/9\\_2023](https://platform.skyciv.com/structural?preload_name=Butch%20Tucker%202&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023)

Public Model Link:

[https://platform.skyciv.com/structural-viewer?project\\_id=Hlf8ts1wbT2NSFEORIDffjx1UyWHLAYlazS0DkxcFikfyuKNmclldsGhpoYibZmw](https://platform.skyciv.com/structural-viewer?project_id=Hlf8ts1wbT2NSFEORIDffjx1UyWHLAYlazS0DkxcFikfyuKNmclldsGhpoYibZmw)

## Array Specification

<b>Product:</b>	Beam
<b>Unique ID:</b>	4P-22.5-8TOP-XD-57-L-5Hx15W-6L83
<b>Duty Classification:</b>	XD
<b>Module Width:</b>	44.02 in
<b>Module Length:</b>	68.11in
<b>Number of Rows:</b>	5
<b>Number of Columns:</b>	15
<b>Total Number of Modules:</b>	75
<b>Desired Tilt Angle:</b>	20
<b>Front Edge Clearance:</b>	10
<b>Total Array Height at Tilt:</b>	16.31 ft
<b>Total Frame Length:</b>	84.50 ft
<b>Frame Weight:</b>	6174 lbs
<b>Array Dimensions N/S:</b>	18.55 ft
<b>Array Dimensions E/W:</b>	86.39 ft
<b>Rail Length:</b>	222.60 in
<b>Rail Spacing:</b>	2.84 ft
<b>Rail Check:</b>	Not Checked

## Support Specifications

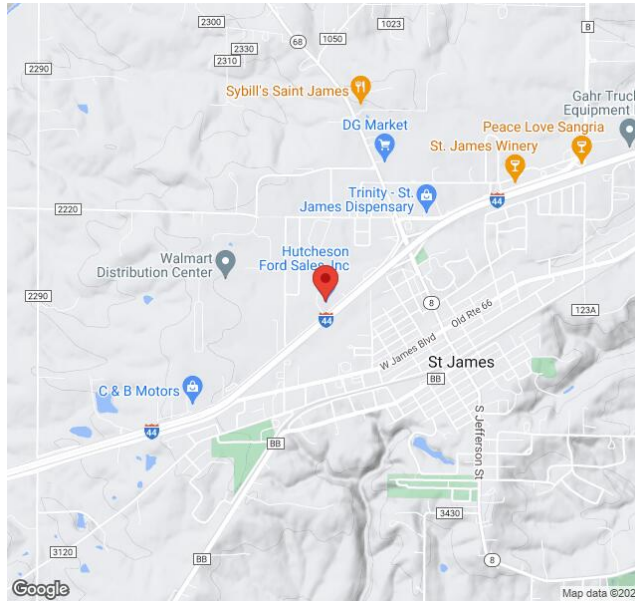
<b>Pole Size:</b>	8in Pipe Sch 40
<b>Pole Length above Grade:</b>	13.17 ft
<b>Number of Poles:</b>	4
<b>Pole Spacing:</b>	22.5 ft

## Foundation Specifications

<b>Foundation Type:</b>	Square
<b>Foundation Dimensions:</b>	48 x 48 in
<b>Foundation Depth (below grade):</b>	Pile 1: 7.00 ft Pile 2: 7.00 ft Pile 3: 7.00 ft Pile 4: 7.00 ft
<b>Foundation Volume:</b>	16.593 y <sup>3</sup>
<b>Foundation Result:</b>	PASSED
<b>Mount Twist:</b>	0.284735 kip

## Site Info

<b>Risk Category:</b>	I
<b>Exposure:</b>	C
<b>Soil Classification:</b>	sand
<b>Site Location:</b>	308 N Outer Rd, St James, MO 65559, USA
<b>Wind Speed:</b>	100 mph
<b>Snow Load:</b>	20 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

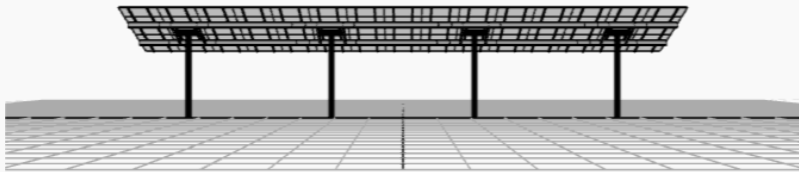
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

### AutoDesigner Input

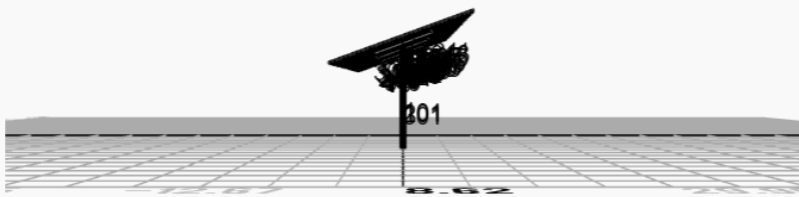
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### Design Notes:

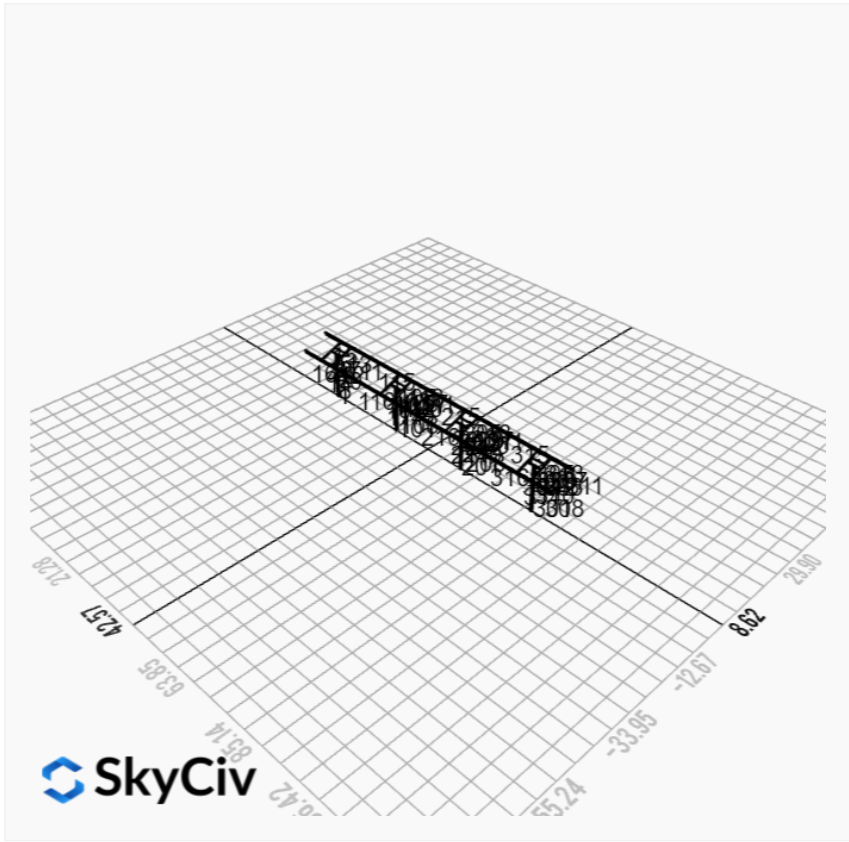
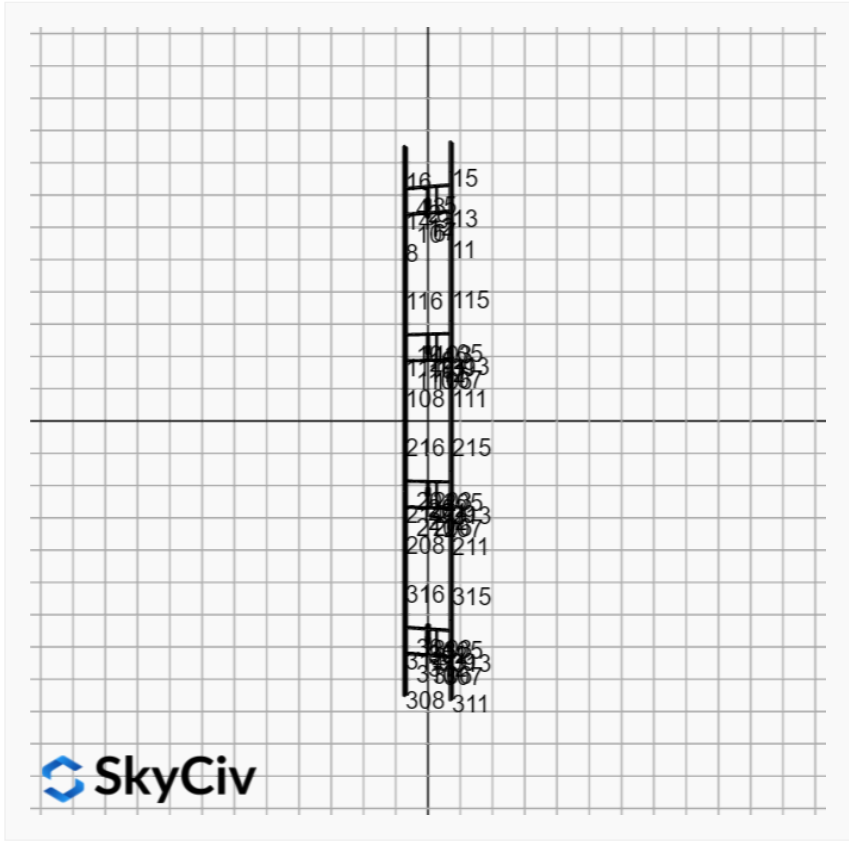
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Foundation Design and Sizing is approximate only

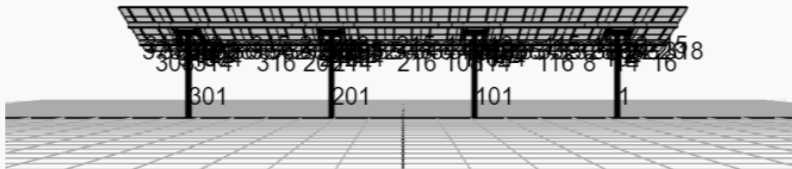


 SkyCiv

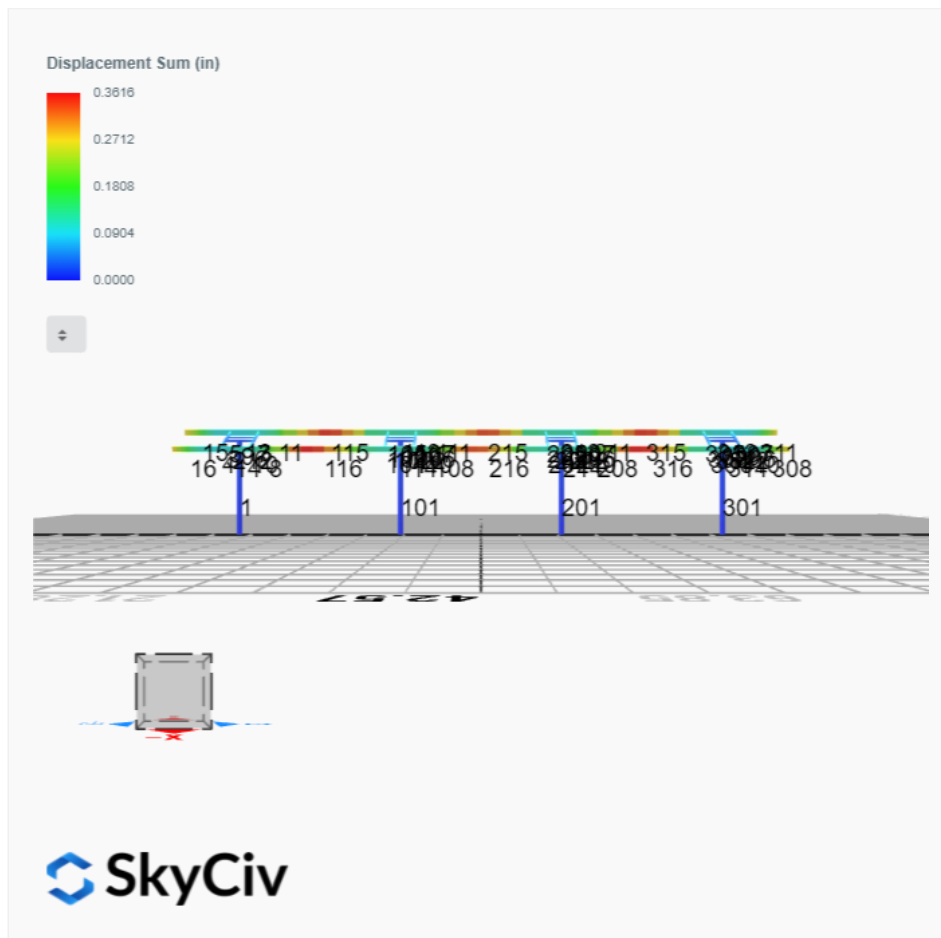


 SkyCiv

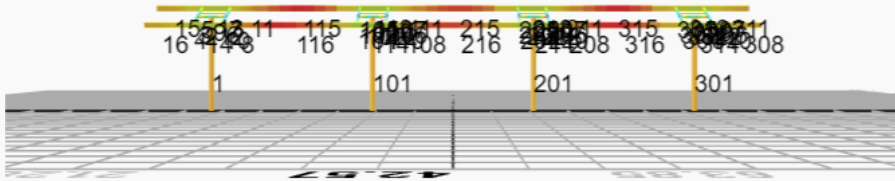




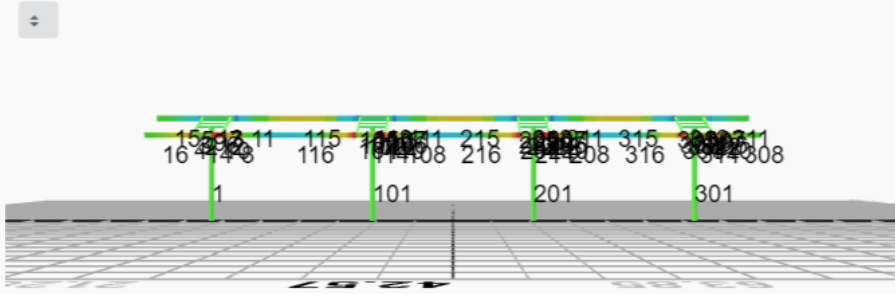
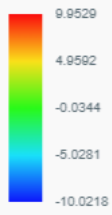
## FEM Results (Envelope Worst Case for each member)



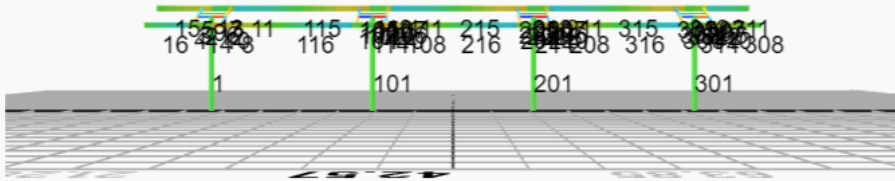
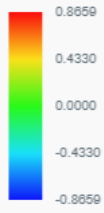
Top Bending Stress Z (ksi)



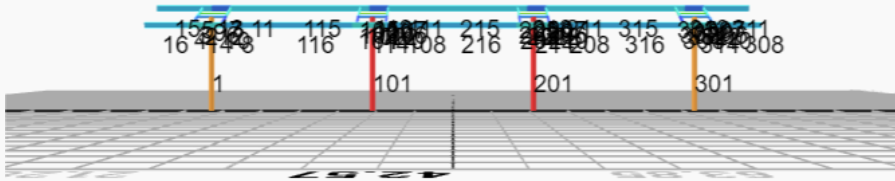
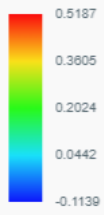
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0079	2.8065	0.0316	0.1304	-0.0046	-0.0654
ULS: 2. D + L	0.0079	2.8065	0.0316	0.1304	-0.0046	-0.0654
ULS: 3. D + (S or Lr or R)	0.0217	6.5487	0.0868	0.3581	-0.0129	-0.2273
ULS: 3. D + (S or Lr or R)	0.0079	2.8065	0.0316	0.1304	-0.0046	-0.0654
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0182	5.6132	0.0730	0.3012	-0.0108	-0.1868
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0079	2.8065	0.0316	0.1304	-0.0046	-0.0654
ULS: 5b. D + 0.7E	0.0079	2.8065	0.0316	0.1304	-0.0046	-0.0654
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0182	5.6132	0.0730	0.3012	-0.0108	-0.1868
ULS: 8. 0.6D + 0.7E	0.0047	1.6839	0.0190	0.0782	-0.0027	-0.0392
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9075	8.0107	0.1325	0.5361	-0.1669	27.3187
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9075	8.0107	0.1325	0.5361	-0.1669	27.3187
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6273	-1.6050	-0.0477	-0.1873	0.1213	-19.6641
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4333	-1.0398	-0.0546	-0.2147	0.1399	-30.9133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4184	9.5163	0.1486	0.6054	-0.1326	20.3513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4184	9.5163	0.1486	0.6054	-0.1326	20.3513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2328	2.3045	0.0135	0.0629	0.0836	-14.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0873	2.7284	0.0083	0.0424	0.0976	-23.3228
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4287	6.7097	0.1072	0.4346	-0.1263	20.4727
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4287	6.7097	0.1072	0.4346	-0.1263	20.4727
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2225	-0.5021	-0.0279	-0.1079	0.0898	-14.7644
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0769	-0.0782	-0.0331	-0.1284	0.1038	-23.2013
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9107	6.8881	0.1198	0.4839	-0.1650	27.3449
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9107	6.8881	0.1198	0.4839	-0.1650	27.3449
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6242	-2.7276	-0.0604	-0.2395	0.1231	-19.6379
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4301	-2.1624	-0.0673	-0.2668	0.1418	-30.8872

### Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.9141
Shear X	-3.1924
Shear Z	0.2361
Moment X	0.9585
Moment Y (Twist)	0.2844
Moment Z	52.9080

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.5163
Shear X	-1.9107
Shear Z	0.1486
Moment X	0.6054
Moment Y (Twist)	0.1669
Moment Z	30.9133

## 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	-0.0079	3.1606	-0.0028	-0.0116	0.0035	0.1313
ULS: 2. D + L	-0.0079	3.1606	-0.0028	-0.0116	0.0035	0.1313
ULS: 3. D + (S or Lr or R)	-0.0217	7.5169	-0.0077	-0.0319	0.0095	0.3158
ULS: 3. D + (S or Lr or R)	-0.0079	3.1606	-0.0028	-0.0116	0.0035	0.1313
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0182	6.4278	-0.0065	-0.0268	0.0080	0.2697
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0079	3.1606	-0.0028	-0.0116	0.0035	0.1313
ULS: 5b. D + 0.7E	-0.0079	3.1606	-0.0028	-0.0116	0.0035	0.1313

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0182	6.4278	-0.0065	-0.0268	0.0080	0.2697
ULS: 8. 0.6D + 0.7E	-0.0047	1.8964	-0.0017	-0.0070	0.0021	0.0788
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1859	9.2029	0.0030	0.0102	-0.0199	31.1715
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1859	9.2029	0.0030	0.0102	-0.0199	31.1715
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8459	-1.9704	-0.0042	-0.0161	0.0153	-22.0291
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5851	-1.2860	-0.0140	-0.0551	0.0373	-34.2734
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6517	10.9596	-0.0022	-0.0105	-0.0095	23.5499
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6517	10.9596	-0.0022	-0.0105	-0.0095	23.5499
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3721	2.5796	-0.0075	-0.0302	0.0168	-16.3506
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1765	3.0929	-0.0149	-0.0594	0.0333	-25.5338
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6414	7.6923	0.0015	0.0047	-0.0140	23.4115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6414	7.6923	0.0015	0.0047	-0.0140	23.4115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3824	-0.6877	-0.0039	-0.0150	0.0123	-16.4890
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1868	-0.1743	-0.0112	-0.0442	0.0288	-25.6722
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1827	7.9387	0.0041	0.0148	-0.0213	31.1190
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.1827	7.9387	0.0041	0.0148	-0.0213	31.1190
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8490	-3.2347	-0.0031	-0.0115	0.0139	-22.0816
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5882	-2.5502	-0.0129	-0.0504	0.0359	-34.3259

### 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	16.0399
Shear X	-3.6440
Shear Z	-0.0260
Moment X	-0.1024
Moment Y (Twist)	0.0670
Moment Z	58.6951

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.9596
Shear X	-2.1859
Shear Z	-0.0149
Moment X	-0.0594
Moment Y (Twist)	0.0373
Moment Z	34.3259

### 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	-0.0079	3.1606	0.0028	0.0116	-0.0034	0.1313
ULS: 2. D + L	-0.0079	3.1606	0.0028	0.0116	-0.0034	0.1313
ULS: 3. D + (S or Lr or R)	-0.0217	7.5169	0.0077	0.0319	-0.0094	0.3158
ULS: 3. D + (S or Lr or R)	-0.0079	3.1606	0.0028	0.0116	-0.0034	0.1313
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0182	6.4278	0.0065	0.0268	-0.0079	0.2697
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0079	3.1606	0.0028	0.0116	-0.0034	0.1313
ULS: 5b. D + 0.7E	-0.0079	3.1606	0.0028	0.0116	-0.0034	0.1313
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0182	6.4278	0.0065	0.0268	-0.0079	0.2697
ULS: 8. 0.6D + 0.7E	-0.0047	1.8964	0.0017	0.0070	-0.0021	0.0788
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1859	9.2029	-0.0030	-0.0102	0.0199	31.1715
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1859	9.2029	-0.0030	-0.0102	0.0199	31.1715
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8459	-1.9704	0.0042	0.0161	-0.0152	-22.0291
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5851	-1.2860	0.0140	0.0551	-0.0373	-34.2733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6517	10.9596	0.0022	0.0105	0.0096	23.5499
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6517	10.9596	0.0022	0.0105	0.0096	23.5499
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3721	2.5796	0.0076	0.0302	-0.0168	-16.3506
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1765	3.0929	0.0149	0.0594	-0.0333	-25.5338

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	-1.6414	7.6923	-0.0015	-0.0047	0.0141	23.4115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6414	7.6923	-0.0015	-0.0047	0.0141	23.4115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3824	-0.6877	0.0039	0.0150	-0.0123	-16.4890
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1868	-0.1743	0.0112	0.0442	-0.0288	-25.6722
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1827	7.9387	-0.0041	-0.0148	0.0213	31.1190
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.1827	7.9387	-0.0041	-0.0148	0.0213	31.1190
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8490	-3.2347	0.0031	0.0115	-0.0139	-22.0816
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5882	-2.5502	0.0129	0.0505	-0.0359	-34.3259

#### 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	16.0399
Shear X	-3.6440
Shear Z	0.0260
Moment X	0.1028
Moment Y (Twist)	0.0670
Moment Z	58.6952

#### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.9596
Shear X	-2.1859
Shear Z	0.0149
Moment X	0.0594
Moment Y (Twist)	0.0373
Moment Z	34.3259

#### 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	0.0079	2.8065	-0.0316	-0.1304	0.0046	-0.0654
ULS: 2. D + L	0.0079	2.8065	-0.0316	-0.1304	0.0046	-0.0654
ULS: 3. D + (S or Lr or R)	0.0217	6.5487	-0.0868	-0.3582	0.0130	-0.2272
ULS: 3. D + (S or Lr or R)	0.0079	2.8065	-0.0316	-0.1304	0.0046	-0.0654
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0182	5.6132	-0.0730	-0.3012	0.0109	-0.1868
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0079	2.8065	-0.0316	-0.1304	0.0046	-0.0654
ULS: 5b. D + 0.7E	0.0079	2.8065	-0.0316	-0.1304	0.0046	-0.0654
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0182	5.6132	-0.0730	-0.3012	0.0109	-0.1868
ULS: 8. 0.6D + 0.7E	0.0047	1.6839	-0.0190	-0.0782	0.0028	-0.0392
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9075	8.0107	-0.1325	-0.5361	0.1669	27.3188
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9075	8.0107	-0.1325	-0.5361	0.1669	27.3188
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6273	-1.6050	0.0477	0.1873	-0.1213	-19.6641
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4333	-1.0398	0.0546	0.2147	-0.1399	-30.9133
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4184	9.5163	-0.1486	-0.6055	0.1326	20.3513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4184	9.5163	-0.1486	-0.6055	0.1326	20.3513
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2328	2.3045	-0.0135	-0.0630	-0.0835	-14.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0873	2.7284	-0.0083	-0.0424	-0.0975	-23.3227
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4287	6.7097	-0.1072	-0.4346	0.1263	20.4727
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4287	6.7097	-0.1072	-0.4346	0.1263	20.4727
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2225	-0.5021	0.0279	0.1079	-0.0898	-14.7644
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0769	-0.0782	0.0331	0.1284	-0.1038	-23.2013
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9107	6.8881	-0.1198	-0.4839	0.1650	27.3449
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9107	6.8881	-0.1198	-0.4839	0.1650	27.3449
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6242	-2.7276	0.0604	0.2395	-0.1231	-19.6379
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4301	-2.1624	0.0673	0.2668	-0.1418	-30.8871

#### 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	13.9141
Shear X	-3.1924
Shear Z	-0.2361
Moment X	-0.9586
Moment Y (Twist)	0.2847
Moment Z	52.9088

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

Result	Value (kip, kip-ft)
Axial	9.5163
Shear X	-1.9107
Shear Z	-0.1486
Moment X	-0.6055
Moment Y (Twist)	0.1669
Moment Z	30.9133

## Project Details

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

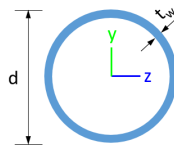


## Design Input Information

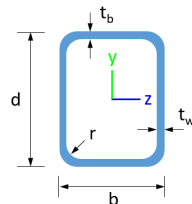
Design Factors			
$\Phi_t$	$\Phi_c$	$\Phi_b$	$\Phi_v$
0.9	0.9	0.9	0.9

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

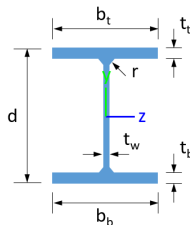
### Section Dimensions



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



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



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

### Section Properties

ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	$I_{yp}$ (in <sup>4</sup> )	$I_{zp}$ (in <sup>4</sup> )	$I_w$ (in <sup>6</sup> )	$S_{yp}$ (in <sup>3</sup> )	$S_{zp}$ (in <sup>3</sup> )
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K <sub>z</sub> L (ft)	K <sub>y</sub> L (ft)	L <sub>b</sub> (ft)	C <sub>b</sub>	L	S	T
1	9	27.66	27.66	13.17	-	3	2	1
2	6	1.30	1.30	2.00	-	3	2	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17	3	2	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.70	3	2	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3	2	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.18,1.18	3	2	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3	2	1
8	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.08,2.34,2.08,2.08,2.09,2.11,2.08,2.08,2.09,2.10,2.08,2.08,2.28,2.08,2.08,2.09,1.61	3	2	1
9	3	2.60	2.60	4.00	-	3	2	1
10	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.72	3	2	1
11	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.11,2.11,2.13,2.16,2.11,2.11,2.11,2.14,2.10,2.10,2.08,1.55,2.11,2.11,2.14,2.24,2.11,2.11,2.11,2.14	3	2	1
12	6	1.30	1.30	2.00	-	3	2	1
13	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.07,1.09,1.08,1.08,1.08,1.09,1.08,1.08,1.09,1.09,1.08,1.08,1.06,1.09,1.08,1.08,1.08,1.09	3	2	1
14	20	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.09,1.19,1.08,1.08,1.09,1.68,1.09,1.09,1.09,1.10,1.08,1.08,1.09,1.14,1.08,1.08,1.09,2.79	3	2	1
15	20	9.97	9.97	4.75	2.33,2.33	3	2	1
16	20	9.97	9.97	4.75	2.33,2.33	3	2	1
101	9	27.66	27.66	13.17	-	3	2	1
102	6	1.30	1.30	2.00	-	3	2	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	3	2	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.71	3	2	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3	2	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	3	2	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	3	2	1

108	20	1.33	1.33	2.0 5	2.26,2.26,2.26,2.26,2.26,2.26,2.25,2.25,2.25,2.36,2.25,2.25,2.25,2.09,2.25,2.25,2.26,2.27,2.25,2.25,2.25,2.34,2.25,2.25,2.25,1.68	3 0 0	2 0 0	1
109	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
110	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.71	3 0 0	2 0 0	1
111	20	1.33	1.33	2.0 5	2.27,2.27,2.27,2.26,2.27,2.27,2.32,2.32,2.13,2.14,2.33,2.33,2.36,2.21,2.29,2.29,2.22,1.59,2.31,2.31,2.11,2.13,2.33,2.33,2.35,2.27	3 0 0	2 0 0	1
112	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
113	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.04,1.07,1.04,1.04,1.04,1.04,1.03,1.03,1.03,1.02,1.03,1.03,1.04,1.08,1.04,1.04,1.04,1.04	3 0 0	2 0 0	1
114	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.23,1.03,1.03,1.03,2.31,1.03,1.03,1.03,1.03,1.03,1.04,1.15,1.03,1.03,1.03,1.28	3 0 0	2 0 0	1
115	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.14,1.14,1.15,1.15,1.15,1.14,1.16,1.16,1.18,1.26,1.16,1.16,1.13,1.13,1.15,1.15,1.15,1.14	3 0 0	2 0 0	1
116	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.17,1.17,1.17,1.13,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.15,1.17,1.17,1.17,1.13	3 0 0	2 0 0	1
201	9	27.6 6	27.6 6	13. 17	-	3 0 0	2 0 0	1
202	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
203	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.18	3 0 0	2 0 0	1
204	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.71	3 0 0	2 0 0	1
205	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	3 0 0	2 0 0	1
206	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	3 0 0	2 0 0	1
207	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
208	20	1.33	1.33	2.0 5	2.30,2.30,2.30,2.30,2.30,2.30,2.29,2.29,2.30,2.12,2.29,2.29,2.30,1.78,2.30,2.30,2.30,2.33,2.29,2.29,2.13,2.29,2.29,2.30,1.36	3 0 0	2 0 0	1
209	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
210	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.71	3 0 0	2 0 0	1
211	20	1.33	1.33	2.0 5	2.32,2.31,2.31,2.31,2.31,2.31,2.19,2.19,2.10,2.10,2.15,2.15,2.13,2.11,2.36,2.36,2.26,1.68,2.24,2.24,2.08,2.09,2.15,2.15,2.14,2.12	3 0 0	2 0 0	1
212	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
213	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.04,1.07,1.04,1.04,1.04,1.04,1.03,1.03,1.03,1.02,1.03,1.03,1.04,1.08,1.04,1.04,1.04,1.04	3 0 0	2 0 0	1
214	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.23,1.03,1.03,1.03,2.31,1.03,1.03,1.03,1.03,1.03,1.04,1.15,1.03,1.03,1.03,1.29	3 0 0	2 0 0	1
215	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.15,1.17,1.17,1.18,1.47,1.16,1.16,1.14,1.15,1.16,1.16,1.16,1.15	3 0 0	2 0 0	1
216	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.18,1.16,1.18,1.18,1.17,1.14,1.18,1.18,1.17,1.17,1.18,1.18,1.16,1.18,1.18,1.17,1.12	3 0 0	2 0 0	1
301	9	27.6 6	27.6 6	13. 17	-	3 0 0	2 0 0	1



103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	116.35	31.17	6.46	56.26	44.91
114	159.30	116.35	31.48	6.46	56.26	44.91
115	159.30	48.27	15.01	6.46	56.26	44.91
116	159.30	48.27	15.01	6.46	56.26	44.91
201	377.97	148.61	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	31.17	6.46	56.26	44.91
214	159.30	116.35	31.48	6.46	56.26	44.91
215	159.30	48.27	15.14	6.46	56.26	44.91
216	159.30	48.27	14.88	6.46	56.26	44.91
301	377.97	148.61	83.29	83.29	113.39	113.39
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	34.37	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	34.37	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	32.39	6.46	56.26	44.91
314	159.30	116.35	33.01	6.46	56.26	44.91
315	159.30	48.27	15.01	6.46	56.26	44.91
316	159.30	48.27	15.01	6.46	56.26	44.91

## Design Ratio

Member ID	P	M <sub>z</sub>	M <sub>y</sub>	V <sub>y</sub>	V <sub>z</sub>	(P,M <sub>z</sub> ,M <sub>y</sub> )	Worst LC	KL/r	φ	Status
1	0.094	0.635	0.026	0.028	0.002	0.641	#16	0.565	Not Required	Pass
2	0.003	0.390	0.114	0.084	0.021	0.504	#13	0.036	Not Required	Pass
3	0.005	0.616	0.026	0.061	0.005	0.623	#13	0.046	Not Required	Pass
4	0.004	0.574	0.003	0.057	0.000	0.617	#13	0.033	Not Required	Pass

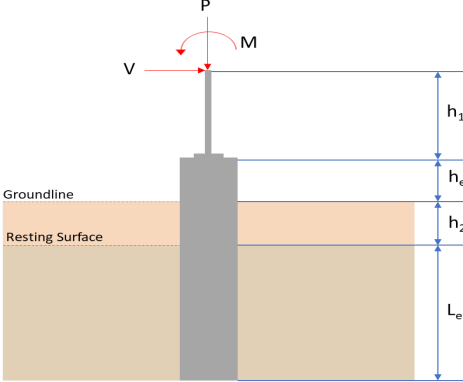
4	U.U04	U.S74	U.U93	U.U57	U.U2U	U.017	#21	U.U82	Not Required	Pass
5	0.004	0.381	0.091	0.061	0.024	0.390	#13	0.076	Not Required	Pass
6	0.006	0.698	0.040	0.070	0.005	0.723	#13	0.046	Not Required	Pass
7	0.006	0.433	0.127	0.069	0.033	0.450	#13	0.076	Not Required	Pass
8	0.001	0.060	0.160	0.042	0.013	0.182	#24	0.102	Not Required	Pass
9	0.012	0.076	0.043	0.002	0.002	0.116	#21	0.206	Not Required	Pass
10	0.006	0.636	0.121	0.064	0.026	0.675	#21	0.082	Not Required	Pass
11	0.002	0.059	0.163	0.047	0.013	0.177	#21	0.102	Not Required	Pass
12	0.002	0.469	0.124	0.095	0.022	0.593	#13	0.054	Not Required	Pass
13	0.004	0.251	0.337	0.058	0.016	0.504	#21	0.306	Not Required	Pass
14	0.005	0.233	0.333	0.053	0.016	0.480	#21	0.204	Not Required	Pass
15	0.000	0.085	0.131	0.030	0.008	0.211	#21	Not Required	Not Required	Pass
16	0.000	0.080	0.131	0.028	0.008	0.208	#21	Not Required	Not Required	Pass
101	0.108	0.705	0.003	0.032	0.000	0.708	#16	0.565	Not Required	Pass
102	0.003	0.496	0.137	0.104	0.024	0.633	#13	0.036	Not Required	Pass
103	0.006	0.751	0.030	0.075	0.001	0.770	#13	0.046	Not Required	Pass
104	0.006	0.710	0.122	0.071	0.026	0.760	#21	0.082	Not Required	Pass
105	0.006	0.466	0.127	0.074	0.033	0.485	#13	0.076	Not Required	Pass
106	0.006	0.758	0.030	0.076	0.002	0.773	#13	0.046	Not Required	Pass
107	0.006	0.471	0.122	0.075	0.032	0.489	#13	0.076	Not Required	Pass
108	0.002	0.065	0.150	0.044	0.013	0.213	#21	0.102	Not Required	Pass
109	0.014	0.075	0.033	0.001	0.000	0.108	#21	0.206	Not Required	Pass
110	0.006	0.706	0.117	0.071	0.025	0.753	#21	0.082	Not Required	Pass
111	0.002	0.059	0.153	0.047	0.013	0.212	#21	0.102	Not Required	Pass
112	0.003	0.498	0.138	0.103	0.025	0.637	#13	0.036	Not Required	Pass
113	0.004	0.275	0.339	0.059	0.016	0.576	#21	0.306	Not Required	Pass
114	0.006	0.280	0.337	0.056	0.016	0.577	#21	0.306	Not Required	Pass
115	0.005	0.501	0.175	0.048	0.013	0.645	#21	0.644	Not Required	Pass
116	0.003	0.464	0.176	0.046	0.013	0.621	#21	0.644	Not Required	Pass
201	0.108	0.705	0.003	0.032	0.000	0.708	#16	0.565	Not Required	Pass
202	0.003	0.498	0.138	0.103	0.025	0.637	#13	0.036	Not Required	Pass
203	0.006	0.758	0.030	0.076	0.002	0.773	#13	0.046	Not Required	Pass
204	0.006	0.706	0.117	0.071	0.025	0.753	#21	0.082	Not Required	Pass
205	0.006	0.470	0.122	0.075	0.032	0.489	#13	0.076	Not Required	Pass
206	0.006	0.751	0.030	0.075	0.001	0.770	#13	0.046	Not Required	Pass
207	0.006	0.466	0.127	0.074	0.033	0.485	#13	0.076	Not Required	Pass
208	0.001	0.061	0.164	0.046	0.013	0.222	#21	0.102	Not Required	Pass
209	0.014	0.075	0.033	0.001	0.000	0.108	#21	0.206	Not Required	Pass
210	0.006	0.710	0.122	0.071	0.026	0.760	#21	0.082	Not Required	Pass
211	0.002	0.052	0.166	0.048	0.013	0.219	#21	0.102	Not Required	Pass
212	0.003	0.496	0.137	0.104	0.024	0.633	#13	0.036	Not Required	Pass
213	0.004	0.275	0.340	0.059	0.016	0.576	#21	0.306	Not Required	Pass
214	0.006	0.280	0.337	0.056	0.016	0.577	#21	0.306	Not Required	Pass
215	0.006	0.460	0.174	0.047	0.013	0.593	#21	0.644	Not Required	Pass
216	0.004	0.399	0.175	0.044	0.013	0.556	#21	0.644	Not Required	Pass
301	0.094	0.635	0.026	0.028	0.002	0.641	#16	0.565	Not Required	Pass
302	0.002	0.469	0.124	0.095	0.022	0.593	#13	0.054	Not Required	Pass
303	0.006	0.698	0.040	0.070	0.005	0.723	#13	0.046	Not Required	Pass
304	0.006	0.636	0.121	0.064	0.026	0.675	#21	0.082	Not Required	Pass
305	0.006	0.433	0.127	0.069	0.033	0.450	#13	0.076	Not Required	Pass
306	0.005	0.616	0.026	0.061	0.005	0.623	#13	0.046	Not Required	Pass
307	0.004	0.381	0.091	0.061	0.024	0.390	#13	0.076	Not Required	Pass
308	0.000	0.080	0.131	0.028	0.008	0.208	#21	Not Required	Not Required	Pass
309	0.012	0.076	0.043	0.002	0.002	0.116	#21	0.206	Not Required	Pass

310	0.004	0.574	0.093	0.057	0.020	0.617	#21	0.082	Not Required	Pass
311	0.000	0.085	0.131	0.030	0.008	0.211	#21	Not Required	Not Required	Pass
312	0.003	0.390	0.114	0.084	0.021	0.504	#13	0.036	Not Required	Pass
313	0.004	0.251	0.336	0.058	0.016	0.504	#21	0.204	Not Required	Pass
314	0.005	0.233	0.333	0.053	0.016	0.480	#21	0.306	Not Required	Pass
315	0.005	0.516	0.175	0.047	0.013	0.647	#21	0.644	Not Required	Pass
316	0.003	0.475	0.175	0.042	0.013	0.628	#21	0.644	Not Required	Pass

## Definitions

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



REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b></p> <p>Pile shape: rectangular  <math>b = 48</math> in - Pile width  <math>D = 48</math> in - Pile depth  <math>L = 7</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>9.516</td> <td>13.914</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-1.911</td> <td>-3.192</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.149</td> <td>0.236</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.605</td> <td>0.959</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>30.913</td> <td>52.908</td> </tr> </tbody> </table> <p><b>Material Properties</b></p> <p><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)	9.516	13.914	$V_x$ (kip)	-1.911	-3.192	$V_z$ (kip)	0.149	0.236	$M_x$ (kipft)	0.605	0.959	$M_z$ (kipft)	30.913	52.908	
Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)																									
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$M_z$ (kipft)	30.913	52.908																										
	<p><b>Required depth to resist lateral loads (ASD)</b></p> <p><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></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.911 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.3043 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(30.913 \text{ kipft}) + ((-1.911 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9225 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.5034 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.149 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.023726 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.605 \text{ kipft}) + ((0.149 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.096338 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 2.2145 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.5034 \text{ ft}), (2.2145 \text{ ft})]$$

$$L_{e,req} = 6.503 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.503 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.929$$

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

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

$$q = \frac{(9.516 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.59475 \text{ kip/ft}^2$$

$$q = 0.09475 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.59475 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.29738$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.3043 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.9225 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.9225 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (4.9225 \text{ kipft/ft})) + (4 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7973 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.9225 \text{ kipft/ft})) + (3 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (4.9225 \text{ kipft/ft})) + (2 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25766 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.9225 \text{ kipft/ft})) + ((-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.94467 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.7973 \text{ ft})}{2}$$

$$p_a = 0.3598 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.25766 \text{ kip/ft}^2)}{(0.3598 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71614$$

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

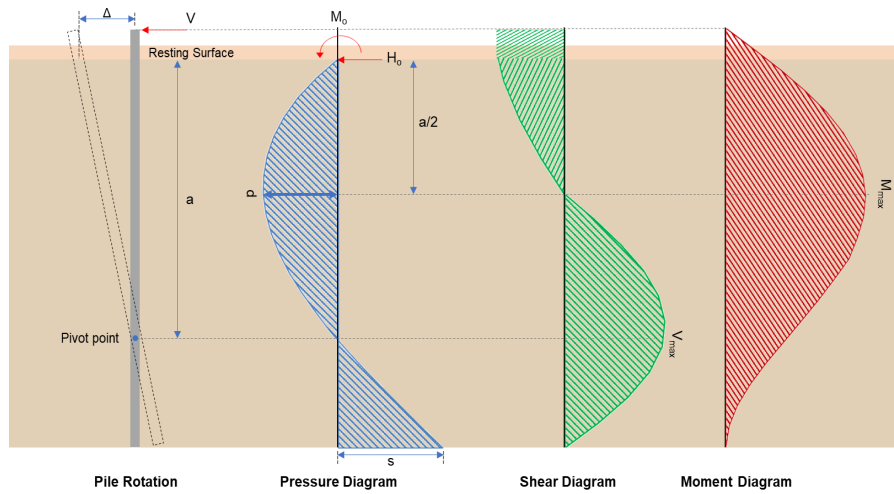
Status: **PASS**  
Ratio: **0.720**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.94467 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.8997$	Status: <b>PASS</b> Ratio: <b>0.900</b>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = 0.023726 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.096338 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.096338 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.023726 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.096338 \text{ kipft/ft})) + (4 \times (0.023726 \text{ kip/ft}) \times (7 \text{ ft}))}$ $a = 4.9786 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.096338 \text{ kipft/ft})) + (3 \times (0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.096338 \text{ kipft/ft})) + (2 \times (0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]}$ $p = 0.019238 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.096338 \text{ kipft/ft})) + ((0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$ $s = 0.04393 \text{ kip/ft}^2$ <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> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.9786 \text{ ft})}{2}$ $p_a = 0.37339 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.019238 \text{ kip/ft}^2)}{(0.37339 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.051522$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: <b>PASS</b> Ratio: <b>0.050</b>

$$Ratio = \frac{(0.04393 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.041838$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.192 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.50828 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(52.908 \text{ kipft}) + ((-3.192 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.4248 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.4248 \text{ kipft/ft})}{(-0.50828 \text{ kip/ft})}$$

$$E = 16.575 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.4248 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.50828 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (8.4248 \text{ kipft/ft})) + (4 \times (-0.50828 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7948 \text{ ft}$$

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

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

$$V_{max} = ((-0.50828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (16.575 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7948 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (16.575 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7948 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.8637 \text{ kip}$$

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

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

$$M_{max} = ((-0.50828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(16.575 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (16.575 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (16.575 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 33.226 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.236 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.03758 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.959 \text{ kipft}) + ((0.236 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.15271 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.15271 \text{ kipft/ft})}{(0.03758 \text{ kip/ft})}$$

$$E = 4.0636 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.15271 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.03758 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.15271 \text{ kipft/ft})) + (4 \times (0.03758 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9785 \text{ ft}$$

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

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

$$V_{max} = ((0.03758 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9785 \text{ ft})}{(7 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9785 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.25434 \text{ kip}$$

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

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

$$M_{max} = ((0.03758 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(4.0636 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.79614 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.914 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.134 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.134 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(13.914 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0052011$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 13.914 \text{ kip} \rightarrow 13914 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13914 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.34 \text{ kip}$$

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

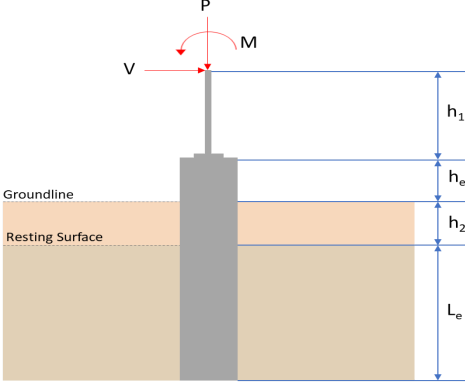
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.34 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.34 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.34 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.3 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 9.8637 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(9.8637 \text{ kip})}{(111.3 \text{ kip})}$ $\text{Ratio} = 0.088621$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.25434 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.25434 \text{ kip})}{(111.3 \text{ kip})}$ $\text{Ratio} = 0.0022851$	<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, LFRD)</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} = 33.226 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(33.226 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.13312$	<p>Status: <b>PASS</b>          Ratio: <b>0.130</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.79614 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.79614 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.0031897$	<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 = 7</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>10.960</td> <td>16.040</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.186</td> <td>-3.644</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.015</td> <td>-0.026</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.059</td> <td>-0.102</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>34.326</td> <td>58.695</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	10.960	16.040	$V_x$ (kip)	-2.186	-3.644	$V_z$ (kip)	-0.015	-0.026	$M_x$ (kipft)	-0.059	-0.102	$M_z$ (kipft)	34.326	58.695	
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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> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.186 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.34809 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(34.326 \text{ kipft}) + ((-2.186 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.4659 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.6779 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.015 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0023885 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.059 \text{ kipft}) + ((-0.015 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.009395 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.85652 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.6779 \text{ ft}), (0.85652 \text{ ft})]$$

$$L_{e,req} = 6.678 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.678 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.954$$

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

**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

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

$$q = \frac{(10.96 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.685 \text{ kip/ft}^2$$

$$q = 0.009 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.685 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.3425$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.34809 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.4659 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.4659 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.4659 \text{ kipft/ft})) + (4 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8003 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.4659 \text{ kipft/ft})) + (3 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.4659 \text{ kipft/ft})) + (2 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.28132 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (5.4659 \text{ kipft/ft})) + ((-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0402 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8003 \text{ ft})}{2}$$

$$p_a = 0.36002 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.28132 \text{ kip/ft}^2)}{(0.36002 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.78139$$

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

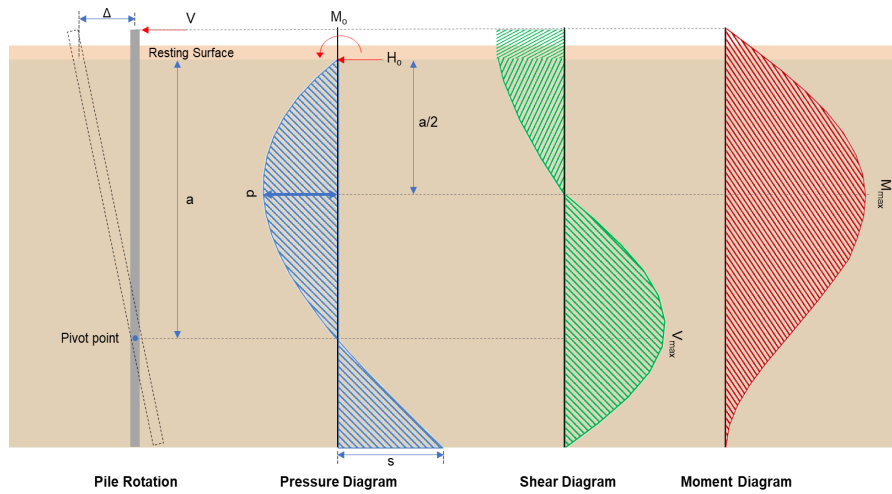
Status: **PASS**  
Ratio: **0.780**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(1.0402 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.9907$	<p>Status: <b>PASS</b> Ratio: <b>0.990</b></p>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = -0.0023885 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.009395 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.009395 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.0023885 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.009395 \text{ kipft/ft})) + (4 \times (-0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))}$ $a = 4.9832 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.009395 \text{ kipft/ft})) + (3 \times (-0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.009395 \text{ kipft/ft})) + (2 \times (-0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]}$ $p = -0.00046094 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.009395 \text{ kipft/ft})) + ((-0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$ $s = 0.00025348 \text{ kip/ft}^2$ <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> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.9832 \text{ ft})}{2}$ $p_a = 0.37374 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.00046094 \text{ kip/ft}^2)}{(0.37374 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.0012333$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	<p>Status: <b>PASS</b> Ratio: <b>0.000</b></p>

$$\text{Ratio} = \frac{(0.00025348 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.00024141$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.644 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.58025 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(58.695 \text{ kipft}) + ((-3.644 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3463 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.3463 \text{ kipft/ft})}{(-0.58025 \text{ kip/ft})}$$

$$E = 16.107 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.3463 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.58025 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (9.3463 \text{ kipft/ft})) + (4 \times (-0.58025 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7977 \text{ ft}$$

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

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

$$V_{max} = ((-0.58025 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7977 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7977 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.985 \text{ kip}$$

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

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

$$M_{max} = ((-0.58025 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(16.107 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 36.968 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.026 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0041401 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.102 \text{ kipft}) + ((-0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016242 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.016242 \text{ kipft/ft})}{(-0.0041401 \text{ kip/ft})}$$

$$E = 3.9231 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.016242 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.0041401 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.016242 \text{ kipft/ft})) + (4 \times (-0.0041401 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9836 \text{ ft}$$

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

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

$$V_{max} = ((-0.0041401 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.9231 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9836 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.9231 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9836 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.027438 \text{ kip}$$

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

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

$$M_{max} = ((-0.0041401 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(3.9231 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9836 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.9231 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9836 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.9231 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9836 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.085677 \text{ kipft}$$

### 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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(16.04 \text{ kip})}{(0.65)(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.063 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.063 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

$$\text{Ratio} = \frac{(16.04 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.005996$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 16.04 \text{ kip} \rightarrow 16040 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16040 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.62 \text{ kip}$$

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

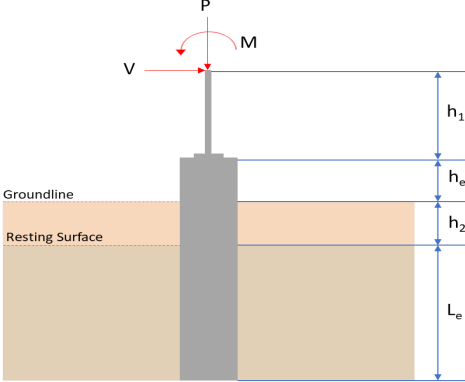
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.62 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.62 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.62 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.49 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.985 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.985 \text{ kip})}{(111.49 \text{ kip})}$ $\text{Ratio} = 0.098535$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.027438 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.027438 \text{ kip})}{(111.49 \text{ kip})}$ $\text{Ratio} = 0.00024611$	<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} = 36.968 \text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(36.968 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.14811$	<p>Status: <b>PASS</b>  Ratio: <b>0.150</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.085677 \text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.085677 \text{kipft})}{(249.6 \text{kipft})}$ $\text{Ratio} = 0.00034326$	<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></p> <p>Pile shape: rectangular  <math>b = 48</math> in - Pile width  <math>D = 48</math> in - Pile depth  <math>L = 7</math> ft - Total pile length  <math>h_1 = 0</math> ft - Lateral load height from the top of the pile,  <math>h_2 = 0</math> ft - Depth to resting surface  <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>10.960</td> <td>16.040</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.186</td> <td>-3.644</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.015</td> <td>0.026</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.059</td> <td>0.103</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>34.326</td> <td>58.695</td> </tr> </tbody> </table> <p><b>Material Properties</b></p> <p><math>f'_{ck} = 2.5</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	10.960	16.040	$V_x$ (kip)	-2.186	-3.644	$V_z$ (kip)	0.015	0.026	$M_x$ (kipft)	0.059	0.103	$M_z$ (kipft)	34.326	58.695	
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	<p><b>Required depth to resist lateral loads (ASD)</b></p> <p><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></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.186 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.34809 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(34.326 \text{ kipft}) + ((-2.186 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.4659 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.6779 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.015 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0023885 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.059 \text{ kipft}) + ((0.015 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.009395 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.96157 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.6779 \text{ ft}), (0.96157 \text{ ft})]$$

$$L_{e,req} = 6.678 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.678 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.954$$

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

**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

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

$$q = \frac{(10.96 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.685 \text{ kip/ft}^2$$

$$q = 0.009 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$Ratio = \frac{(0.685 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.3425$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.34809 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 5.4659 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (5.4659 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.4659 \text{ kipft/ft})) + (4 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8003 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.4659 \text{ kipft/ft})) + (3 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.4659 \text{ kipft/ft})) + (2 \times (-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.28132 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (5.4659 \text{ kipft/ft})) + ((-0.34809 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0402 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8003 \text{ ft})}{2}$$

$$p_a = 0.36002 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.28132 \text{ kip/ft}^2)}{(0.36002 \text{ kip/ft}^2)}$$

$$Ratio = 0.78139$$

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

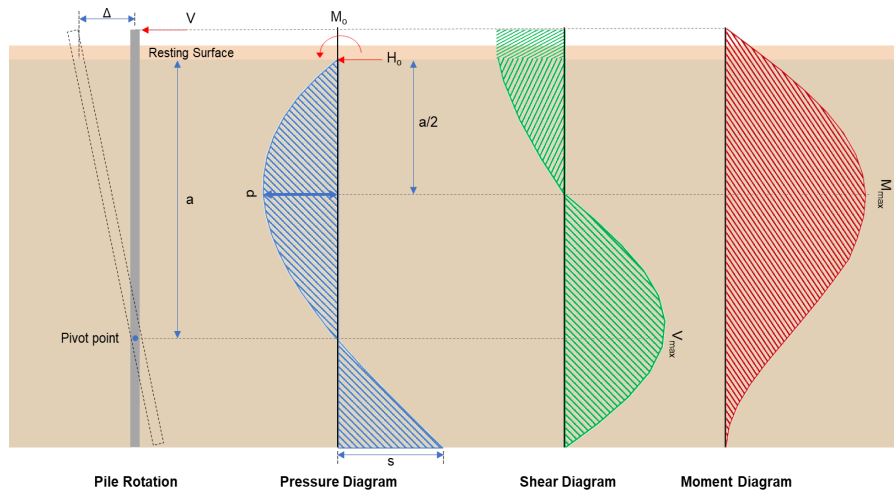
Status: **PASS**  
Ratio: **0.780**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(1.0402 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.9907$	Status: <b>PASS</b> Ratio: <b>0.990</b>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = 0.0023885 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.009395 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.009395 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.0023885 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.009395 \text{ kipft/ft})) + (4 \times (0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))}$ $a = 4.9832 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.009395 \text{ kipft/ft})) + (3 \times (0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.009395 \text{ kipft/ft})) + (2 \times (0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]}$ $p = 0.001912 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.009395 \text{ kipft/ft})) + ((0.0023885 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$ $s = 0.0043481 \text{ kip/ft}^2$ <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> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.9832 \text{ ft})}{2}$ $p_a = 0.37374 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.001912 \text{ kip/ft}^2)}{(0.37374 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.005116$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: <b>PASS</b> Ratio: <b>0.010</b>

$$Ratio = \frac{(0.0043481 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.0041411$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.644 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.58025 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(58.695 \text{ kipft}) + ((-3.644 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3463 \text{ kipft/ft}$$

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

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

$$E = \frac{(9.3463 \text{ kipft/ft})}{(-0.58025 \text{ kip/ft})}$$

$$E = 16.107 \text{ ft}$$

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

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

$$a = \frac{(4 \times (9.3463 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.58025 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (9.3463 \text{ kipft/ft})) + (4 \times (-0.58025 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7977 \text{ ft}$$

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

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

$$V_{max} = ((-0.58025 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7977 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7977 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.985 \text{ kip}$$

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

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

$$M_{max} = ((-0.58025 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(16.107 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (16.107 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7977 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 36.968 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.026 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0041401 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.103 \text{ kipft}) + ((0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016401 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.016401 \text{ kipft/ft})}{(0.0041401 \text{ kip/ft})}$$

$$E = 3.9615 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.016401 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.0041401 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.016401 \text{ kipft/ft})) + (4 \times (0.0041401 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9822 \text{ ft}$$

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

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

$$V_{max} = ((0.0041401 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (3.9615 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9822 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (3.9615 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9822 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.027597 \text{ kip}$$

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

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

$$M_{max} = ((0.0041401 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(3.9615 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9822 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (3.9615 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9822 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (3.9615 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9822 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.086234 \text{ kipft}$$

### 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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(16.04 \text{ kip})}{(0.65)(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.063 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.063 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

$n_{rebar}$  - 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

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

$$\text{Ratio} = \frac{(16.04 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.005996$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 16.04 \text{ kip} \rightarrow 16040 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16040 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.62 \text{ kip}$$

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

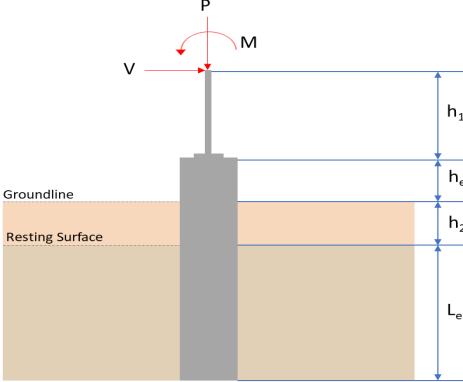
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.62 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.62 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.62 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.49 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 10.985 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(10.985 \text{ kip})}{(111.49 \text{ kip})}$ $\text{Ratio} = 0.098535$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.027597 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.027597 \text{ kip})}{(111.49 \text{ kip})}$ $\text{Ratio} = 0.00024754$	<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} = 36.968 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(36.968 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.14811$	<p>Status: <b>PASS</b>          Ratio: <b>0.150</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.086234 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.086234 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.00034549$	<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></p> <p>Pile shape: rectangular  <math>b = 48</math> in - Pile width  <math>D = 48</math> in - Pile depth  <math>L = 7</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>9.516</td> <td>13.914</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-1.911</td> <td>-3.192</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.149</td> <td>-0.236</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.605</td> <td>-0.959</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>30.913</td> <td>52.909</td> </tr> </tbody> </table> <p><b>Material Properties</b></p> <p><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)	9.516	13.914	$V_x$ (kip)	-1.911	-3.192	$V_z$ (kip)	-0.149	-0.236	$M_x$ (kipft)	-0.605	-0.959	$M_z$ (kipft)	30.913	52.909	
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	<p><b>Required depth to resist lateral loads (ASD)</b></p> <p><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></p> <p><math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.911 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.3043 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(30.913 \text{ kipft}) + ((-1.911 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.9225 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.5034 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.149 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.023726 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.605 \text{ kipft}) + ((-0.149 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.096338 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.7364 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(6.5034 \text{ ft}), (1.7364 \text{ ft})]$$

$$L_{e,req} = 6.503 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

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

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

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(6.503 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.929$$

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

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

$$q = \frac{(9.516 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.59475 \text{ kip/ft}^2$$

$$q = 0.09475 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.59475 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.29738$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

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

$$L/D = 1.75$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.3043 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 4.9225 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (4.9225 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (4.9225 \text{ kipft/ft})) + (4 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7973 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.9225 \text{ kipft/ft})) + (3 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (4.9225 \text{ kipft/ft})) + (2 \times (-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.25766 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (4.9225 \text{ kipft/ft})) + ((-0.3043 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.94467 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.7973 \text{ ft})}{2}$$

$$p_a = 0.3598 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.25766 \text{ kip/ft}^2)}{(0.3598 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71614$$

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

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.94467 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.8997$$

Status: **PASS**  
Ratio: **0.900**

**Considering z-direction:**

$H_o = -0.023726 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.096338 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.096338 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.023726 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.096338 \text{ kipft/ft})) + (4 \times (-0.023726 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9786 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.096338 \text{ kipft/ft})) + (3 \times (-0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 [(3 \times (0.096338 \text{ kipft/ft})) + (2 \times (-0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = -0.0045209 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 [(2 \times (0.096338 \text{ kipft/ft})) + ((-0.023726 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.0032562 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.9786 \text{ ft})}{2}$$

$$p_a = 0.37339 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0045209 \text{ kip/ft}^2)}{(0.37339 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.012108$$

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

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

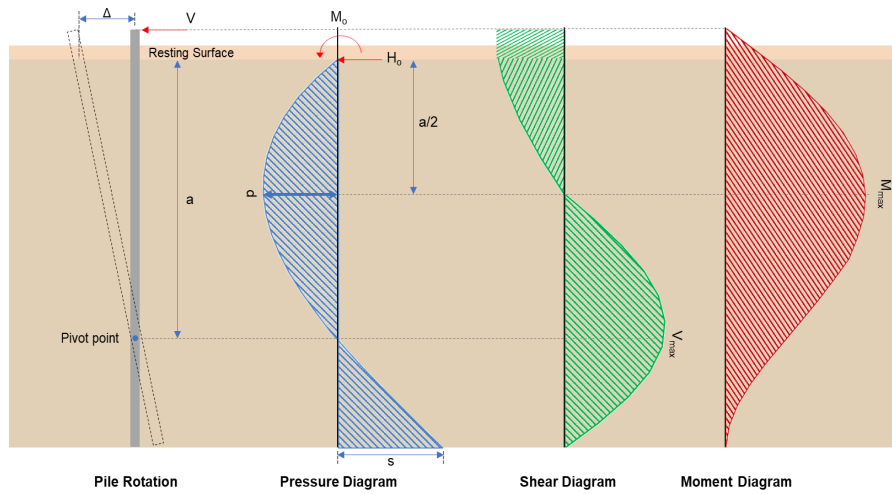
$$\text{Ratio} = \frac{s}{p_s}$$

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

$$\text{Ratio} = \frac{(0.0032562 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.0031011$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-3.192 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.50828 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(52.909 \text{ kipft}) + ((-3.192 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.425 \text{ kipft/ft}$$

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

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

$$E = \frac{(8.425 \text{ kipft/ft})}{(-0.50828 \text{ kip/ft})}$$

$$E = 16.576 \text{ ft}$$

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

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

$$a = \frac{(4 \times (8.425 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.50828 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (8.425 \text{ kipft/ft})) + (4 \times (-0.50828 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.7948 \text{ ft}$$

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

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

$$V_{max} = ((-0.50828 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (16.576 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7948 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (16.576 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7948 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.8639 \text{ kip}$$

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

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

$$M_{max} = ((-0.50828 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(16.576 \text{ ft})}{(7 \text{ ft})} + \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (16.576 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (16.576 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.7948 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 33.226 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.236 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.03758 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.959 \text{ kipft}) + ((-0.236 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.15271 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.15271 \text{ kipft/ft})}{(-0.03758 \text{ kip/ft})}$$

$$E = 4.0636 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.15271 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.03758 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.15271 \text{ kipft/ft})) + (4 \times (-0.03758 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.9785 \text{ ft}$$

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

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

$$V_{max} = ((-0.03758 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9785 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9785 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.25434 \text{ kip}$$

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

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

$$M_{max} = ((-0.03758 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[ \left( \frac{(4.0636 \text{ ft})}{(7 \text{ ft})} + \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left( \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.0636 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left( \frac{(4.9785 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.79614 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

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

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.914 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.134 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-84.134 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

25.7.2.2

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

25.7.2.1

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

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

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

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

#### Summary:

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$\text{Ratio} = \frac{(13.914 \text{ kip})}{(2675.2 \text{ kip})}$$

$$\text{Ratio} = 0.0052011$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

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

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$ ,  $P = 13.914 \text{ kip} \rightarrow 13914 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13914 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.34 \text{ kip}$$

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

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.34 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.34 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.34 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.3 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 9.8639 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(9.8639 \text{ kip})}{(111.3 \text{ kip})}$ $\text{Ratio} = 0.088622$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.25434 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.25434 \text{ kip})}{(111.3 \text{ kip})}$ $\text{Ratio} = 0.0022851$	<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} = 33.226 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(33.226 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.13312$	<p>Status: <b>PASS</b>          Ratio: <b>0.130</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 0.79614 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.79614 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.0031897$	<p>Status: <b>PASS</b>          Ratio: <b>0.000</b></p>