

# Your Project Calculations



Project Name: Boxpower SPS2 4x6

S3D Model Link:

[https://platform.skyciv.com/structural?preload\\_name=Boxpower%20SPS2%204x6&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/6\\_2023](https://platform.skyciv.com/structural?preload_name=Boxpower%20SPS2%204x6&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023)

Public Model Link:

[https://platform.skyciv.com/structural-viewer?project\\_id=vnLMkCluUNkr0AVdGzlkCvEO5fth1iejE7eQhNfdd8RRcfrsSnkBvmSEbkFom2UR](https://platform.skyciv.com/structural-viewer?project_id=vnLMkCluUNkr0AVdGzlkCvEO5fth1iejE7eQhNfdd8RRcfrsSnkBvmSEbkFom2UR)

## Array Specification

Product:	Beam
Unique ID:	3P-17-8TOP-XD-12-L-4Hx6W-A60D
Duty Classification:	XD
Module Width:	44.65 in
Module Length:	89.69in
Number of Rows:	4
Number of Columns:	6
Total Number of Modules:	24
Desired Tilt Angle:	50
Front Edge Clearance:	8
Total Array Height at Tilt:	19.47 ft
Total Frame Length:	43.50 ft
Frame Weight:	3040 lbs
Array Dimensions N/S:	15.05 ft
Array Dimensions E/W:	45.34 ft
Rail Length:	180.60 in
Rail Spacing:	3.78 ft
Rail Check:	FAIL (128% utilized)

## Support Specifications

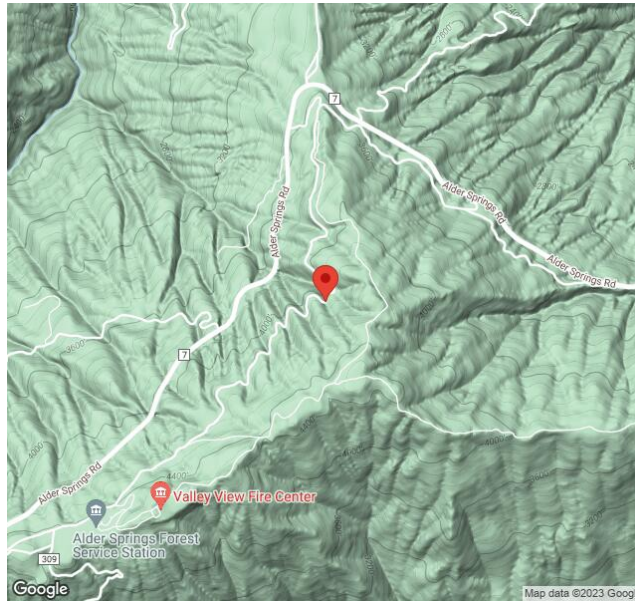
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	13.76 ft
Number of Poles:	3
Pole Spacing:	17 ft

## Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø48 in
Foundation Depth (below grade):	Pile 1: 9.50 ft Pile 2: 9.75 ft Pile 3: 9.50 ft
Foundation Volume:	13.381 y <sup>3</sup>
Foundation Result:	PASSED
Mount Twist:	1.715126 kip

## Site Info

Risk Category:	III
Exposure:	C
Soil Classification:	sand
Site Location:	Rd 307, California, USA
Wind Speed:	100 mph
Snow Load:	152 psf
Design Uplift Pressure:	0.027779 ksf
Design Downforce Pressure:	-0.027779 ksf
Design Snow Pressure:	0.045965 ksf



### Design Disclaimer

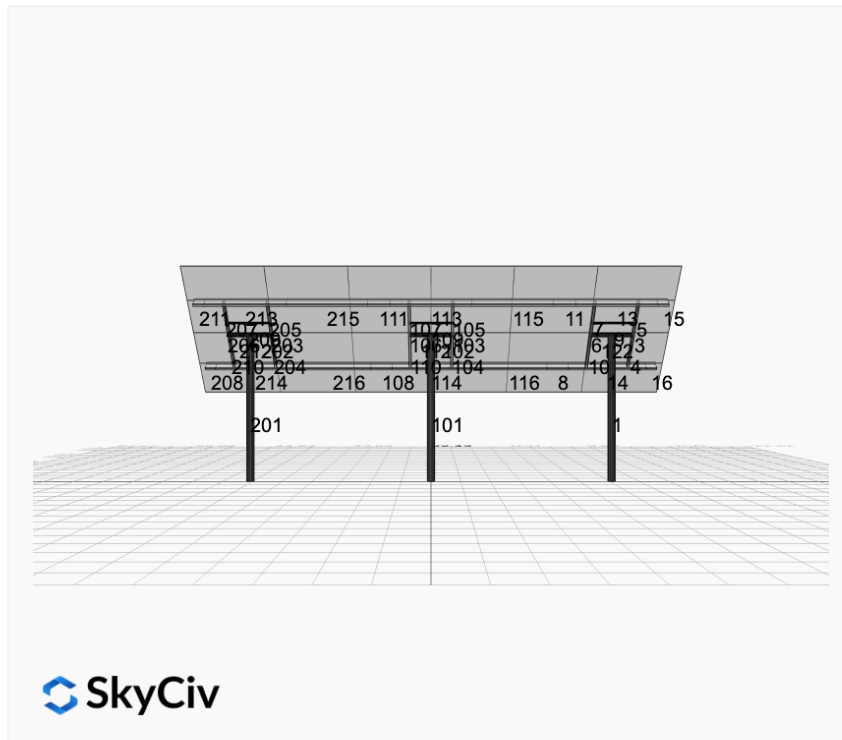
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

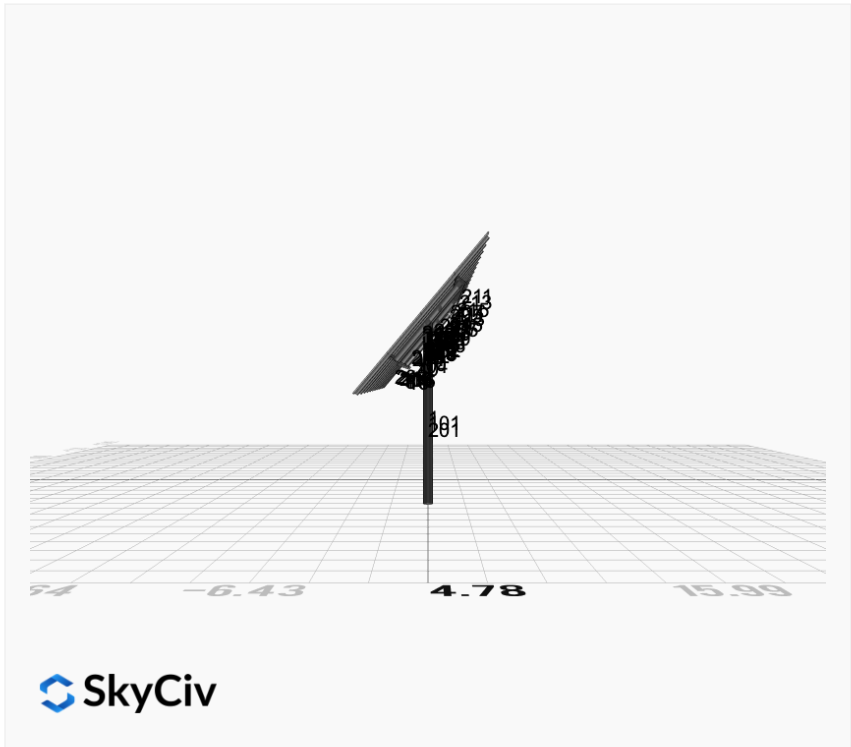
### AutoDesigner Input

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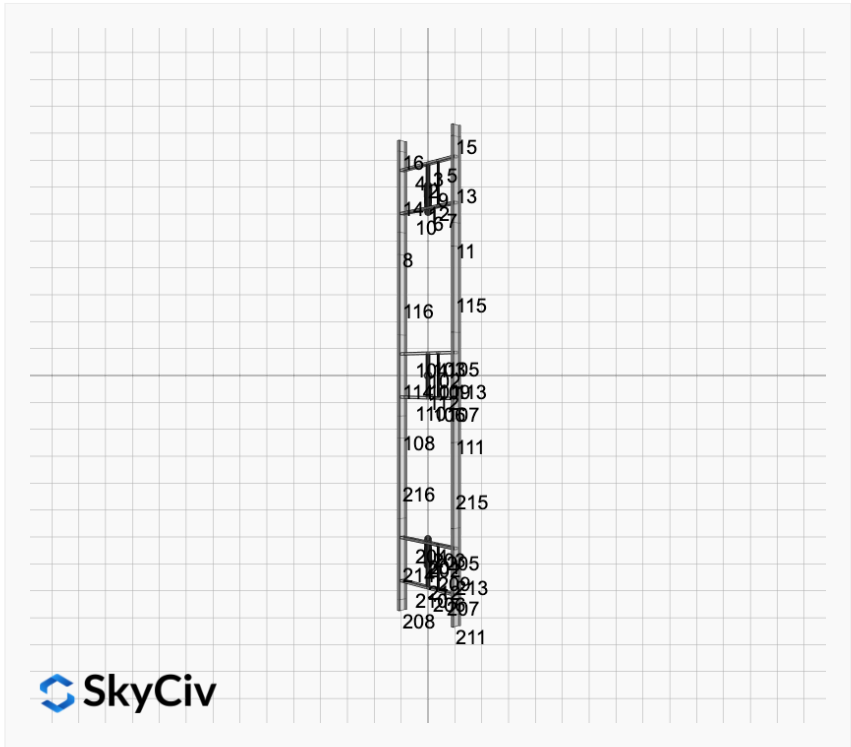
### Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent

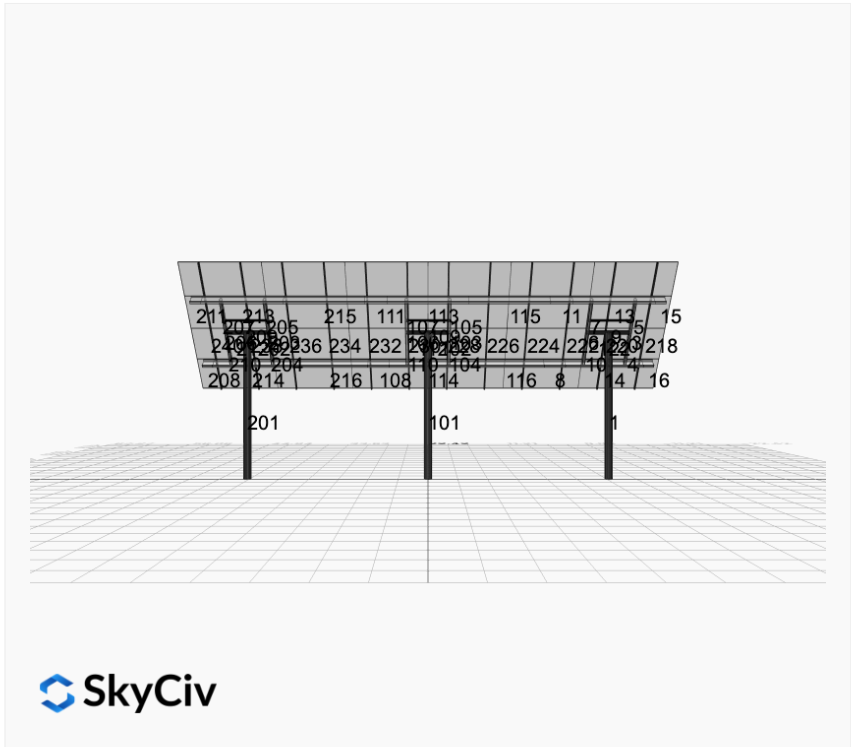
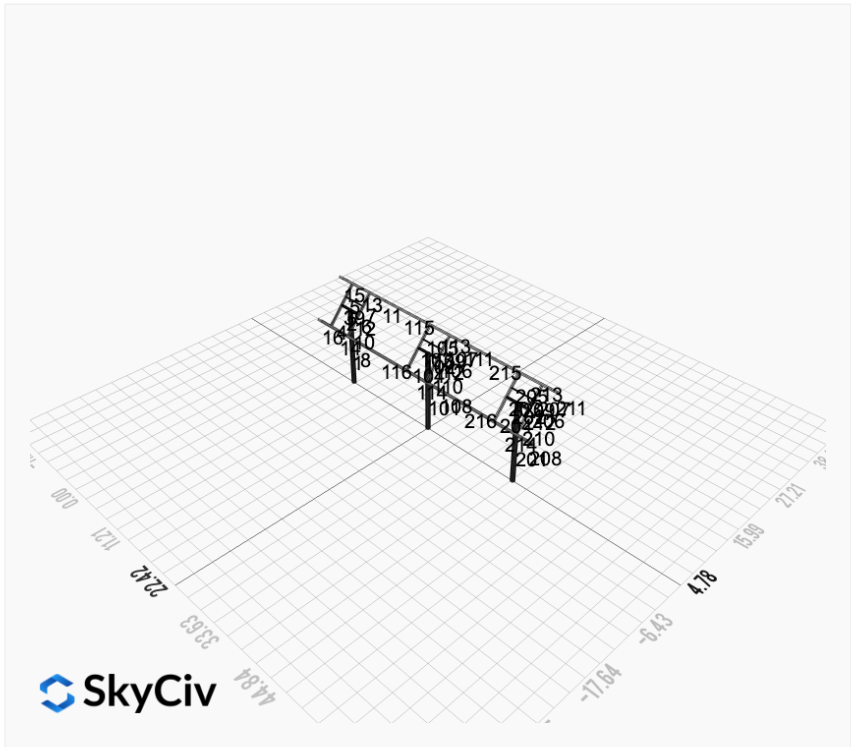




SkyCiv



SkyCiv



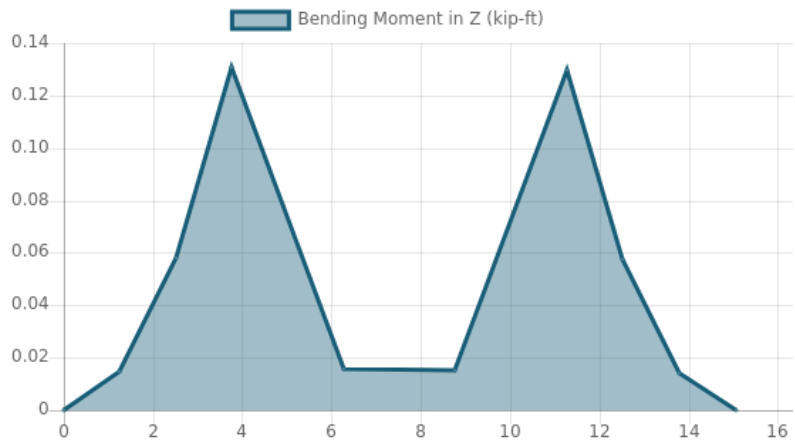
**Rail Design Check**

**Rail Length:** 15.049999999999999 ft  
**Additional Restraints Required:** None  
**Tributary Width:** 3.77875 ft  
**Material:** Aluminium  
**Density:** 169 lb/ft<sup>3</sup>  
**Elasticity Modulus:** 10000 ksi  
**Fy:** 34.5 ksi  
**Fu:** 37 ksi  
**Snow (X):** 0.1116 kip/ft  
**Snow (Y):** -0.1331 kip/ft  
**Wind uplift Case A:** 0.1050 kip/ft  
**Wind downforce Case A:** 0.1050 kip/ft  
**Dead (Panel load) (X):** 0.0110 kip/ft  
**Dead (Panel load) (Y):** -0.0131 kip/ft

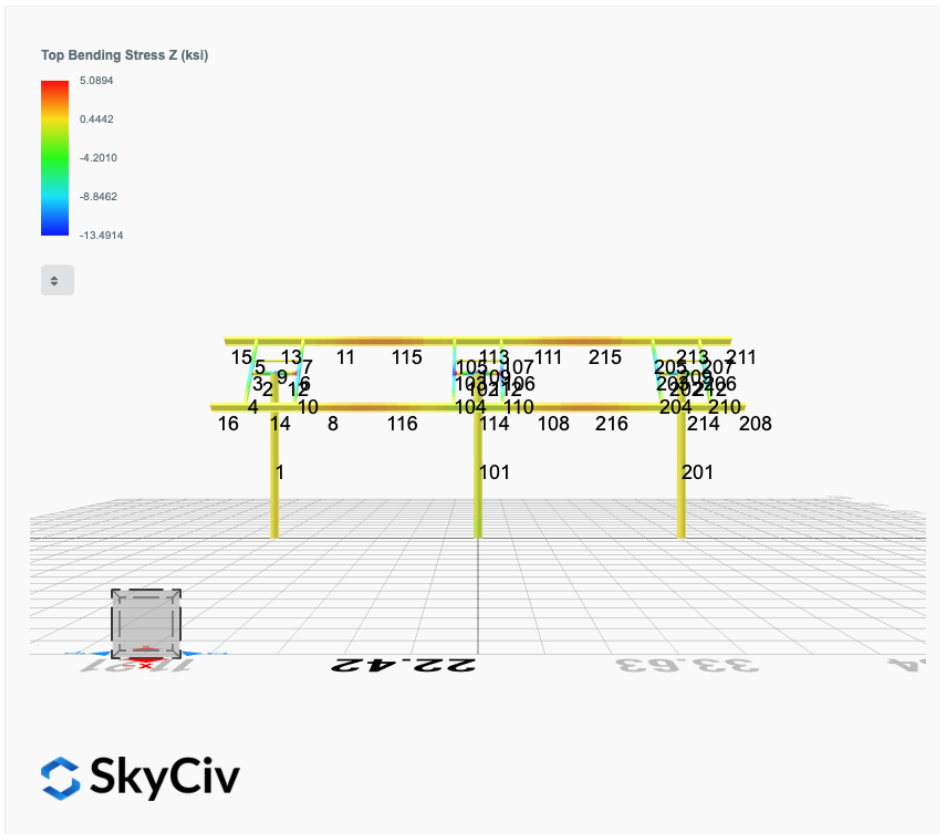
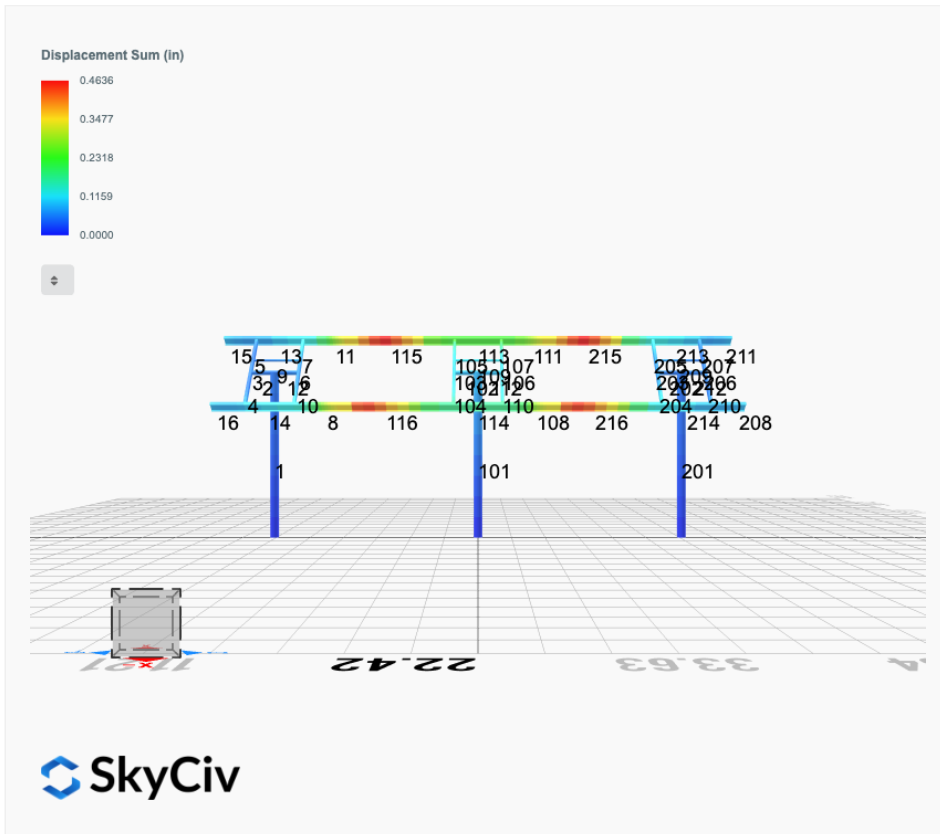


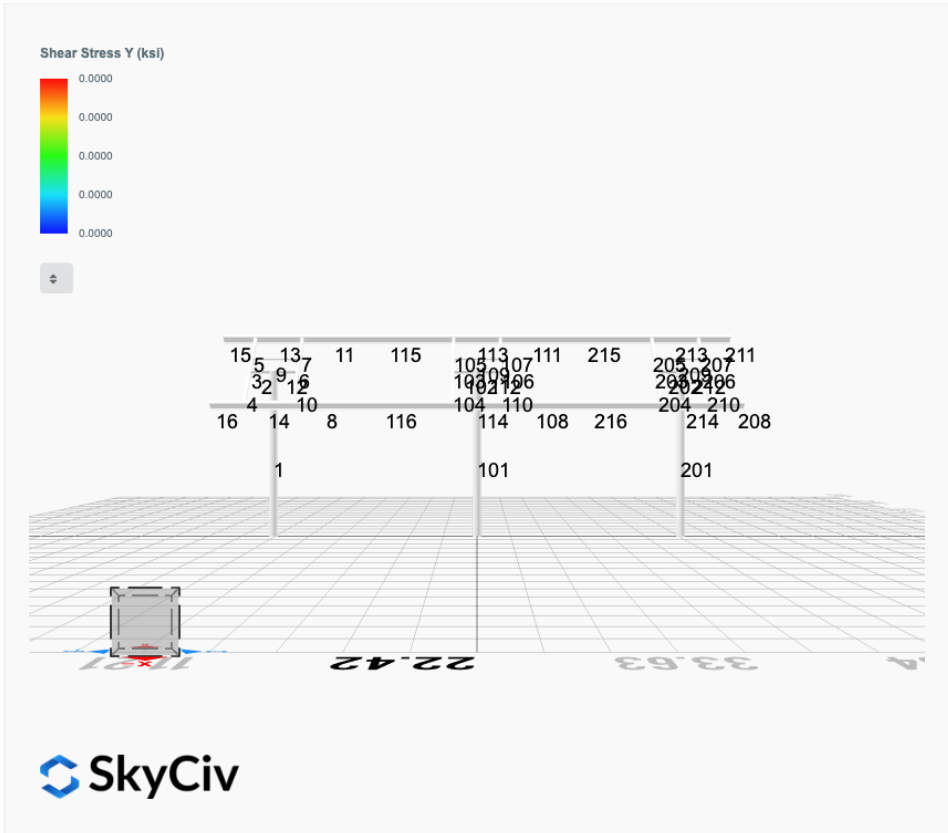
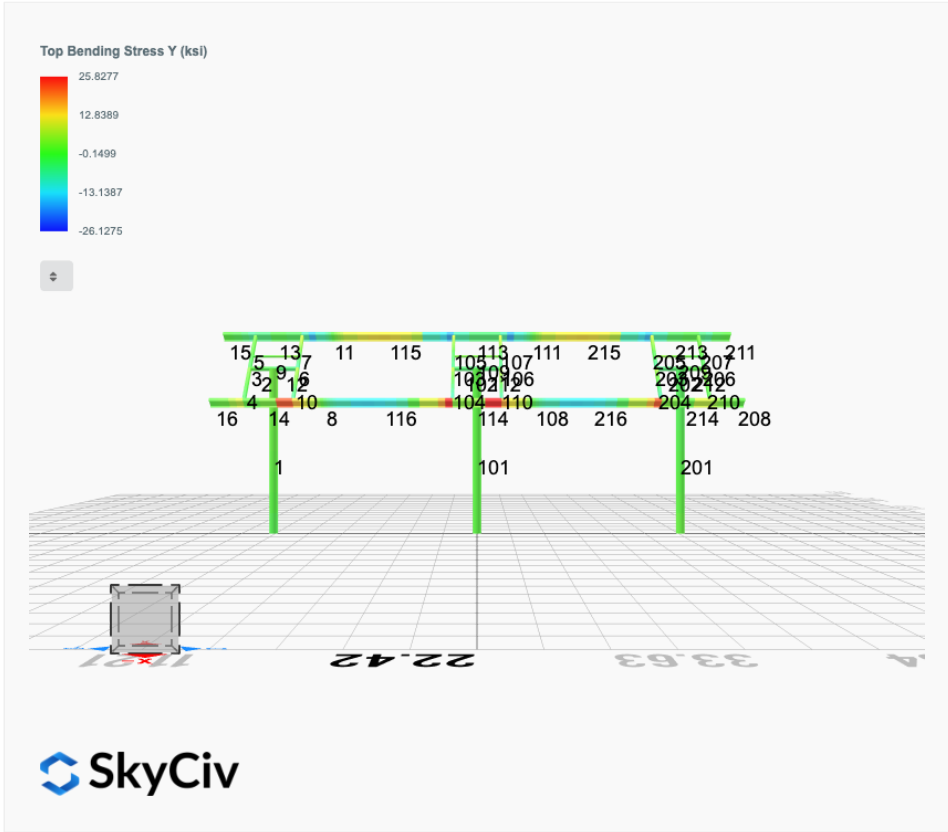
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	44.32715012	1.285	FAIL
Material Yield	34.5	44.32715012	1.285	FAIL
Material Strength	37	44.32715012	1.198	FAIL

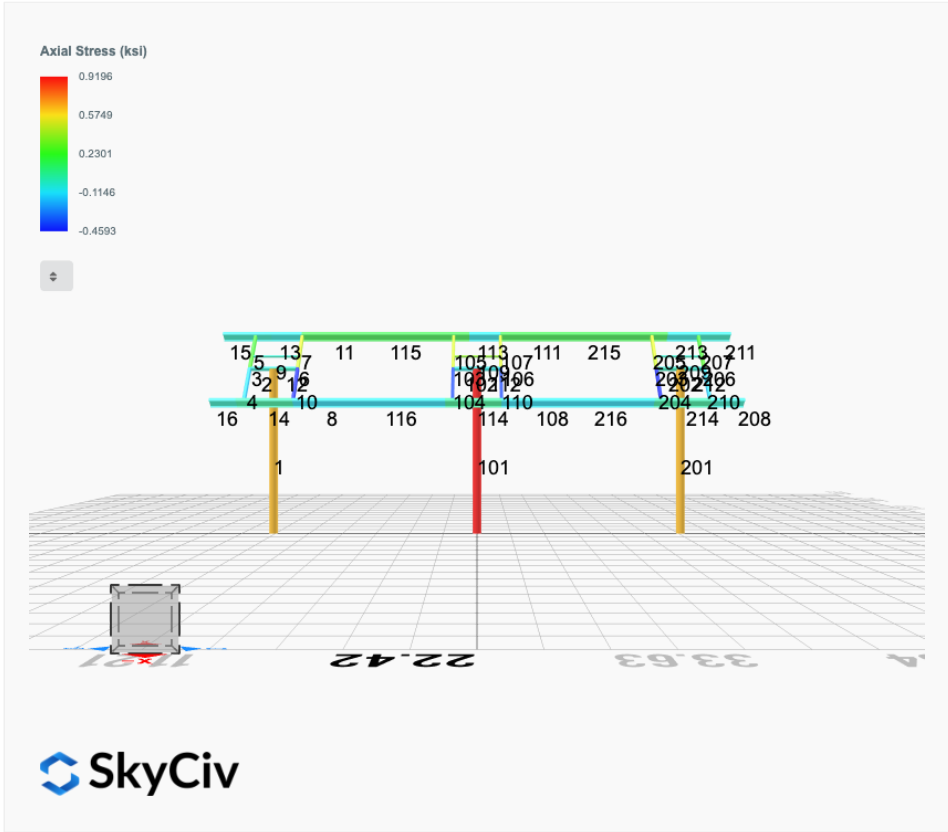
**Member 1, ULS: 1.14D**



# FEM Results (Envelope Worst Case for each member)







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

### ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 2. D + L	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 3. D + (S or Lr or R)	0.0757	7.7163	0.2606	1.1442	-0.3294	-0.8029
ULS: 3. D + (S or Lr or R)	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0601	6.2639	0.2068	0.9081	-0.2613	-0.6348
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 5b. D + 0.7E	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0601	6.2639	0.2068	0.9081	-0.2613	-0.6348
ULS: 8. 0.6D + 0.7E	0.0081	1.1441	0.0274	0.1199	-0.0343	-0.0783
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7325	4.1394	0.2239	0.9544	-0.9516	38.7118
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7506	-0.3203	-0.1286	-0.5357	0.8179	-37.5950
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9994	7.9384	0.3405	1.4741	-0.9321	28.4969
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0601	6.2639	0.2068	0.9081	-0.2613	-0.6348
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1129	4.5936	0.0761	0.3565	0.3950	-28.7332
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0601	6.2639	0.2068	0.9081	-0.2613	-0.6348
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0460	3.5812	0.1793	0.7658	-0.7279	29.0012
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0663	0.2365	-0.0851	-0.3518	0.5992	-28.2289
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0135	1.9068	0.0456	0.1998	-0.0571	-0.1304
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7379	3.3767	0.2057	0.8745	-0.9287	38.7640
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0081	1.1441	0.0274	0.1199	-0.0343	-0.0783
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7452	-1.0830	-0.1469	-0.6156	0.8407	-37.5428
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0081	1.1441	0.0274	0.1199	-0.0343	-0.0783

### 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	13.4529
Shear X	-4.6205
Shear Z	0.5536
Moment X	2.4165
Moment Y (Twist)	1.7154
Moment Z	66.0298

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.9384
Shear X	-2.7506
Shear Z	0.3405
Moment X	1.4741
Moment Y (Twist)	0.9516
Moment Z	38.7640

## 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	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 2. D + L	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 3. D + (S or Lr or R)	-0.1513	10.0402	0.0000	-0.0000	0.0001	1.8204
ULS: 3. D + (S or Lr or R)	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1202	8.1092	0.0000	-0.0000	0.0000	1.4472
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 5b. D + 0.7E	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1202	8.1092	0.0000	-0.0000	0.0000	1.4472
ULS: 8. 0.6D + 0.7E	-0.0162	1.3898	0.0000	0.0000	0.0000	0.1966
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.2484	5.1626	0.0000	0.0000	0.0000	44.7482
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.2124	-0.5410	0.0000	0.0000	0.0000	-42.6013
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5363	10.2439	0.0000	-0.0000	0.0000	34.7626
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1202	8.1092	0.0000	-0.0000	0.0000	1.4472
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3093	5.9662	0.0000	-0.0000	0.0000	-30.7495
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.1202	8.1092	0.0000	-0.0000	0.0000	1.4472
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4430	4.4511	0.0000	0.0000	0.0000	33.6430
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.4025	0.1733	0.0000	0.0000	0.0000	-31.8691
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0269	2.3164	0.0000	0.0000	0.0000	0.3276
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.2376	4.2360	0.0000	0.0000	0.0000	44.6172
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0162	1.3898	0.0000	0.0000	0.0000	0.1966
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.2231	-1.4676	0.0000	0.0000	0.0000	-42.7324
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0162	1.3898	0.0000	0.0000	0.0000	0.1966

#### Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.4915
Shear X	-5.4389
Shear Z	0.0000
Moment X	0.0002
Moment Y (Twist)	0.0004
Moment Z	77.1118

#### 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	10.2439
Shear X	-3.2484
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0001
Moment Z	44.7482

#### 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	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 2. D + L	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 3. D + (S or Lr or R)	0.0757	7.7162	-0.2606	-1.1444	0.3295	-0.8028
ULS: 3. D + (S or Lr or R)	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0601	6.2639	-0.2068	-0.9082	0.2614	-0.6347
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 5b. D + 0.7E	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0601	6.2639	-0.2068	-0.9082	0.2614	-0.6347
ULS: 8. 0.6D + 0.7E	0.0081	1.1441	-0.0274	-0.1199	0.0343	-0.0783
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.7325	4.1394	-0.2239	-0.9544	0.9516	38.7118
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.7506	-0.3203	0.1286	0.5357	-0.8179	-37.5950
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9994	7.9384	-0.3405	-1.4742	0.9322	28.4970
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0601	6.2639	-0.2068	-0.9082	0.2614	-0.6347
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1129	4.5936	-0.0761	-0.3566	-0.3949	-28.7331
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0601	6.2639	-0.2068	-0.9082	0.2614	-0.6347

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0460	3.5812	-0.1793	-0.7658	0.7279	29.0012
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.0663	0.2365	0.0851	0.3518	-0.5992	-28.2289
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0135	1.9068	-0.0456	-0.1998	0.0571	-0.1304
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7379	3.3767	-0.2057	-0.8745	0.9287	38.7640
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0081	1.1441	-0.0274	-0.1199	0.0343	-0.0783
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.7452	-1.0830	0.1469	0.6156	-0.8407	-37.5428
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0081	1.1441	-0.0274	-0.1199	0.0343	-0.0783

### 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	13.4528
Shear X	-4.6204
Shear Z	-0.5536
Moment X	-2.4173
Moment Y (Twist)	1.7151
Moment Z	66.0315

### Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.9384
Shear X	-2.7506
Shear Z	-0.3405
Moment X	-1.4742
Moment Y (Twist)	0.9516
Moment Z	38.7640

## Project Details

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



## Design Input Information

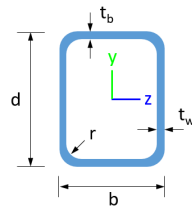
Design Factors			
$\Phi_t$	$\Phi_c$	$\Phi_b$	$\Phi_v$
0.9	0.9	0.9	0.9

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	62.42	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	28.91	28.91	13.76	-	3	2	1
2	6	1.30	1.30	2.00	-	3	2	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.16,1.18,1.17,1.19,1.17,1.19,1.17,1.17,1.18,1.17,1.18,1.19,1.16,1.19,1.17,1.19,1.17,1.19,1.17,1.19	3	2	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.68,1.65,1.68,1.67,1.70,1.66,1.70,1.67,1.67,1.68,1.67,1.68,1.70,1.65,1.70,1.67,1.70,1.66,1.70	3	2	1
5	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.67,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	3	2	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.18,1.19	3	2	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	3	2	1
8	20	1.33	1.33	2.05	1.20,1.20	3	2	1
9	3	2.60	2.60	4.00	-	3	2	1
10	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.68,1.70,1.67,1.68,1.66,1.68,1.67,1.70,1.66,1.70,1.67,1.67,1.68,1.67,1.67,1.70,1.65,1.70,1.67,1.70,1.66,1.70	3	2	1
11	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.22,1.24,1.22,1.27,1.22,1.24,1.22,1.25,1.22,1.23,1.22,1.19,1.22,1.24,1.22,1.26,1.22,1.24,1.22,1.25,1.22	3	2	1
12	6	1.30	1.30	2.00	-	3	2	1
13	20	4.88	4.00	7.50	1.47,1.50,1.47,1.51,1.49,1.47,1.48,1.50,1.47,1.50,1.47,1.47,1.49,1.47,1.49,1.47,1.49,1.51,1.53,1.51,1.47,1.47,1.49,1.47,1.47,1.49,1.47	3	2	1
14	20	4.88	4.00	7.50	1.56,1.61,1.56,1.62,1.59,1.56,1.77,1.61,2.05,1.61,1.79,1.56,1.88,1.56,1.69,1.62,1.46,1.62,1.76,1.56,1.97,1.56,1.80,1.56,1.86,1.56	3	2	1
15	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	3	2	1
16	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	3	2	1
101	9	28.91	28.91	13.76	-	3	2	1
102	6	1.30	1.30	2.00	-	3	2	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.19	3	2	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	3	2	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	3	2	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.19,1.18,1.19	3	2	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	3	2	1

108	20	1.33	1.33	2.0 5	1.39,1.39,1.39,1.39,1.39,1.39,1.27,1.39,1.16,1.39,1.25,1.39,1.22,1.39,1.33,1.39,1.68,1.39,1.2 6,1.39,1.19,1.39,1.24,1.39,1.22,1.39	3 0 0	2 0 0	1
109	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
110	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.6 7,1.69,1.65,1.69,1.67,1.69,1.66,1.69	3 0 0	2 0 0	1
111	20	1.33	1.33	2.0 5	1.28,1.28,1.28,1.28,1.28,1.28,1.15,1.28,1.05,1.28,1.13,1.28,1.10,1.28,1.20,1.28,1.81,1.28,1.1 4,1.28,1.08,1.28,1.13,1.28,1.11,1.28	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	1.09,1.10,1.09,1.10,1.10,1.09,3.78,1.10,1.43,1.10,2.74,1.09,2.03,1.09,2.03,1.10,1.05,1.10,3.4 3,1.09,1.68,1.09,2.63,1.09,2.13,1.09	3 0 0	2 0 0	1
114	20	4.88	4.00	7.5 0	1.06,1.07,1.06,1.07,1.06,1.06,1.10,1.07,4.06,1.07,1.17,1.06,1.72,1.06,1.08,1.07,1.05,1.07,1.1 1,1.06,2.70,1.06,1.22,1.06,1.58,1.06	3 0 0	2 0 0	1
115	20	4.84	4.84	7.4 5	1.09,1.09,1.09,1.09,1.09,1.09,1.05,1.09,1.03,1.09,1.04,1.09,1.04,1.09,1.07,1.09,1.19,1.09,1.0 4,1.09,1.03,1.09,1.04,1.09,1.04,1.09	3 0 0	2 0 0	1
116	20	4.84	4.84	7.4 5	1.12,1.12,1.12,1.12,1.12,1.12,1.09,1.12,1.05,1.12,1.08,1.12,1.07,1.12,1.10,1.12,1.18,1.12,1.0 8,1.12,1.06,1.12,1.08,1.12,1.07,1.12	3 0 0	2 0 0	1
201	9	28.9 1	28.9 1	13. 76	-	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	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.1 9,1.19,1.18,1.19,1.18,1.19,1.18,1.19	3 0 0	2 0 0	1
204	17	2.44	2.44	3.7 5	1.70,1.68,1.70,1.67,1.68,1.70,1.67,1.68,1.66,1.68,1.67,1.70,1.66,1.70,1.67,1.67,1.68,1.67,1.6 7,1.70,1.65,1.70,1.67,1.70,1.66,1.70	3 0 0	2 0 0	1
205	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.6 7,1.68,1.66,1.68,1.67,1.68,1.66,1.68	3 0 0	2 0 0	1
206	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.16,1.18,1.17,1.19,1.17,1.19,1.17,1.17,1.18,1.17,1.1 8,1.19,1.16,1.19,1.17,1.19,1.17,1.19	3 0 0	2 0 0	1
207	17	1.52	1.52	2.3 3	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.67,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.6 7,1.69,1.65,1.69,1.67,1.69,1.66,1.69	3 0 0	2 0 0	1
208	20	2.10	2.10	1.0 0	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.3 3,2.32,2.33,2.32,2.33,2.33,2.33,2.33	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	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.68,1.65,1.68,1.67,1.70,1.66,1.70,1.67,1.67,1.68,1.67,1.6 8,1.70,1.65,1.70,1.67,1.70,1.66,1.70	3 0 0	2 0 0	1
211	20	2.10	2.10	1.0 0	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.3 3,2.32,2.33,2.32,2.33,2.33,2.33,2.33	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	1.47,1.50,1.47,1.51,1.49,1.47,1.48,1.50,1.47,1.50,1.47,1.47,1.49,1.47,1.49,1.51,1.54,1.51,1.4 7,1.47,1.49,1.47,1.47,1.47,1.49,1.47	3 0 0	2 0 0	1
214	20	4.88	4.00	7.5 0	1.56,1.61,1.56,1.62,1.59,1.56,1.77,1.61,2.05,1.61,1.80,1.56,1.88,1.56,1.69,1.62,1.45,1.62,1.7 6,1.56,1.97,1.56,1.80,1.56,1.86,1.56	3 0 0	2 0 0	1
215	20	4.84	4.84	7.4 5	1.07,1.07,1.07,1.07,1.07,1.07,1.09,1.07,1.14,1.07,1.09,1.07,1.11,1.07,1.08,1.07,1.06,1.07,1.0 9,1.07,1.12,1.07,1.10,1.07,1.10,1.07	3 0 0	2 0 0	1
216	20	4.84	4.84	7.4 5	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.07,1.06,1.06,1.06,1.06,1.0 6,1.06,1.07,1.06,1.06,1.06,1.07,1.06	3 0 0	2 0 0	1

Member Design Capacity

## Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	136.11	83.29	83.29	113.39	113.39
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	116.35	44.92	6.46	56.26	44.91
14	159.30	116.35	44.62	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	377.97	136.11	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	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	32.09	6.46	56.26	44.91
114	159.30	116.35	32.09	6.46	56.26	44.91
115	159.30	104.63	31.66	6.46	56.26	44.91
116	159.30	104.63	32.27	6.46	56.26	44.91
201	377.97	136.11	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	137.23	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	137.23	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	44.92	6.46	56.26	44.91
214	159.30	116.35	44.31	6.46	56.26	44.91
215	159.30	104.63	32.58	6.46	56.26	44.91
216	159.30	104.63	32.58	6.46	56.26	44.91

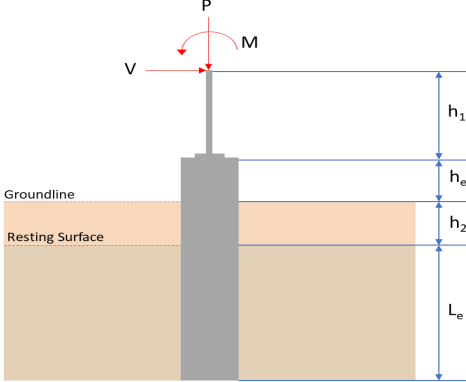
## Design Ratio

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	0.099	0.793	0.062	0.041	0.005	0.849	#13	0.590	Not Required	Pass
2	0.001	0.256	0.131	0.065	0.027	0.350	#21	0.054	Not Required	Pass
3	0.010	0.396	0.055	0.038	0.013	0.456	#21	0.046	Not Required	Pass
4	0.009	0.385	0.086	0.038	0.020	0.476	#21	0.082	Not Required	Pass
5	0.009	0.246	0.050	0.039	0.012	0.255	#21	0.076	Not Required	Pass
6	0.018	0.558	0.178	0.056	0.056	0.744	#21	0.046	Not Required	Pass
7	0.019	0.346	0.237	0.054	0.058	0.393	#21	0.076	Not Required	Pass
8	0.007	0.114	0.213	0.029	0.034	0.329	#21	0.102	Not Required	Pass
9	0.002	0.048	0.096	0.005	0.005	0.110	#23	0.206	Not Required	Pass
10	0.019	0.524	0.227	0.052	0.052	0.673	#21	0.082	Not Required	Pass
11	0.009	0.119	0.212	0.032	0.033	0.336	#21	0.102	Not Required	Pass
12	0.001	0.447	0.195	0.108	0.038	0.588	#21	0.054	Not Required	Pass
13	0.011	0.059	0.672	0.044	0.046	0.685	#23	0.306	Not Required	Pass
14	0.007	0.060	0.660	0.041	0.046	0.671	#23	0.204	Not Required	Pass
15	0.000	0.004	0.024	0.007	0.007	0.028	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.024	0.007	0.007	0.028	#21	Not Required	Not Required	Pass
101	0.129	0.926	0.000	0.048	0.000	0.968	#13	0.590	Not Required	Warn
102	0.003	0.458	0.199	0.113	0.036	0.617	#21	0.054	Not Required	Pass
103	0.018	0.601	0.132	0.059	0.030	0.740	#21	0.046	Not Required	Pass
104	0.018	0.627	0.248	0.062	0.056	0.816	#21	0.082	Not Required	Pass
105	0.018	0.374	0.256	0.058	0.065	0.437	#21	0.076	Not Required	Pass
106	0.018	0.601	0.132	0.059	0.030	0.740	#21	0.046	Not Required	Pass
107	0.018	0.374	0.256	0.058	0.065	0.437	#21	0.076	Not Required	Pass
108	0.007	0.098	0.213	0.034	0.035	0.273	#21	0.102	Not Required	Pass
109	0.016	0.023	0.052	0.001	0.000	0.082	#21	0.206	Not Required	Pass
110	0.018	0.627	0.248	0.062	0.056	0.816	#21	0.082	Not Required	Pass
111	0.009	0.126	0.220	0.031	0.034	0.302	#21	0.102	Not Required	Pass
112	0.003	0.458	0.199	0.113	0.036	0.617	#21	0.054	Not Required	Pass
113	0.011	0.112	0.716	0.043	0.047	0.739	#23	0.306	Not Required	Pass
114	0.008	0.102	0.706	0.046	0.047	0.784	#21	0.306	Not Required	Pass
115	0.013	0.211	0.377	0.031	0.034	0.595	#21	0.370	Not Required	Pass
116	0.007	0.184	0.369	0.034	0.035	0.558	#21	0.370	Not Required	Pass
201	0.099	0.793	0.062	0.041	0.005	0.849	#13	0.590	Not Required	Pass
202	0.001	0.447	0.195	0.108	0.038	0.588	#21	0.054	Not Required	Pass
203	0.018	0.558	0.178	0.056	0.056	0.744	#21	0.046	Not Required	Pass
204	0.019	0.524	0.227	0.052	0.052	0.673	#21	0.082	Not Required	Pass
205	0.019	0.346	0.237	0.054	0.058	0.393	#21	0.076	Not Required	Pass
206	0.010	0.396	0.055	0.038	0.013	0.456	#21	0.046	Not Required	Pass
207	0.009	0.246	0.050	0.039	0.012	0.255	#21	0.076	Not Required	Pass
208	0.000	0.004	0.024	0.007	0.007	0.028	#21	Not Required	Not Required	Pass
209	0.002	0.048	0.096	0.005	0.005	0.110	#23	0.206	Not Required	Pass
210	0.009	0.385	0.086	0.038	0.020	0.476	#21	0.082	Not Required	Pass
211	0.000	0.004	0.024	0.007	0.007	0.028	#21	Not Required	Not Required	Pass
212	0.001	0.256	0.131	0.065	0.027	0.350	#21	0.054	Not Required	Pass
213	0.011	0.059	0.672	0.044	0.046	0.684	#23	0.204	Not Required	Pass
214	0.007	0.060	0.660	0.041	0.046	0.671	#23	0.306	Not Required	Pass
215	0.013	0.214	0.377	0.032	0.033	0.594	#21	0.370	Not Required	Pass
216	0.007	0.195	0.370	0.029	0.034	0.567	#21	0.370	Not Required	Pass

## Definitions

Φ<sub>t</sub> Safety factor for tensile

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

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: round <math>D = 48</math> in - Pile diameter <math>L = 9.5</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>7.938</td> <td>13.453</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.751</td> <td>-4.620</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.341</td> <td>0.554</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>1.474</td> <td>2.417</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>38.764</td> <td>66.030</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 3</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	7.938	13.453	$V_x$ (kip)	-2.751	-4.620	$V_z$ (kip)	0.341	0.554	$M_x$ (kipft)	1.474	2.417	$M_z$ (kipft)	38.764	66.030	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.751 \text{ kip})}{(48 \text{ in})}$ $H_o = -0.68775 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(38.764 \text{ kipft}) + ((-2.751 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 9.691 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.6839 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.341 \text{ kip})}{(48 \text{ in})}$$

$$H_o = 0.08525 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.474 \text{ kipft}) + ((0.341 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.3685 \text{ kipft/ft}$$

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:

$L_{e,z} = 4.3284 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(8.6839 \text{ ft}), (4.3284 \text{ ft})]$$

$$L_{e,req} = 8.684 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (9.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9.5 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(8.684 \text{ ft})}{(9.5 \text{ ft})}$$

$$\text{Ratio} = 0.91411$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(48 \text{ in})}{2}\right)^2$$

$$A = 12.566 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.938 \text{ kip})}{(12.566 \text{ ft}^2)}$$

$$q = 0.63169 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.63169 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.31584$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.68775 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 9.691 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (9.691 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (9.691 \text{ kipft/ft})) + (4 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.5788 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.691 \text{ kipft/ft})) + (3 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]^2}{(9.5 \text{ ft})^2 \times [(3 \times (9.691 \text{ kipft/ft})) + (2 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = 0.29947 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (9.691 \text{ kipft/ft})) + ((-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = 1.3418 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.5788 \text{ ft})}{2}$$

$$p_a = 0.49341 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.29947 \text{ kip/ft}^2)}{(0.49341 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.60694$$

Status: **PASS**  
Ratio: **0.610**

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9.5 \text{ ft})$$

$$p_s = 1.425 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.3418 \text{ kip/ft}^2)}{(1.425 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.9416$$

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

**Considering z-direction:**

$H_o = 0.08525 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.3685 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.3685 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (0.08525 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (0.3685 \text{ kipft/ft})) + (4 \times (0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.8039 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.3685 \text{ kipft/ft})) + (3 \times (0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]^2}{(9.5 \text{ ft})^2 \times [(3 \times (0.3685 \text{ kipft/ft})) + (2 \times (0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = 0.072984 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.3685 \text{ kipft/ft})) + ((0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = 0.16154 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.8039 \text{ ft})}{2}$$

$$p_a = 0.51029 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.072984 \text{ kip/ft}^2)}{(0.51029 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.14302$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9.5 \text{ ft})$$

$$p_s = 1.425 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

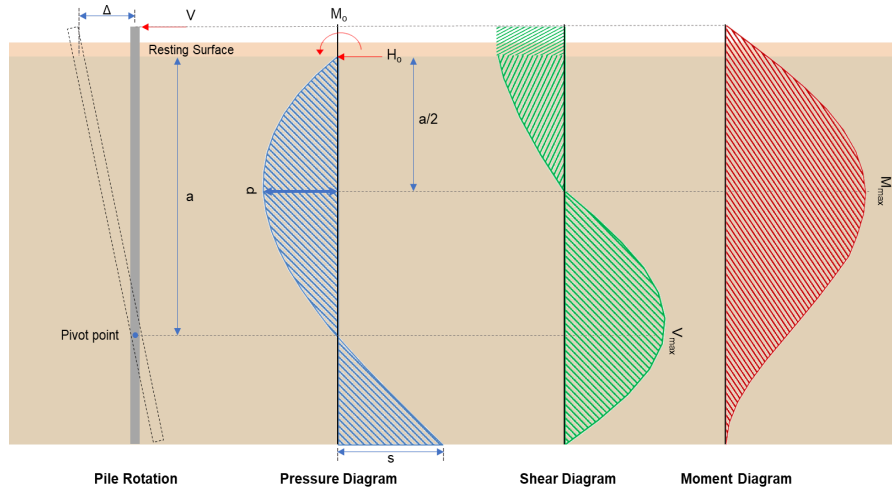
Status: **PASS**  
Ratio: **0.140**

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

$$Ratio = \frac{(0.16154 \text{ kip/ft}^2)}{(1.425 \text{ kip/ft}^2)}$$

$$Ratio = 0.11336$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-4.62 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -1.155 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(66.03 \text{ kipft}) + ((-4.62 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 16.508 \text{ kipft/ft}$$

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

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

$$E = \frac{(16.508 \text{ kipft/ft})}{(-1.155 \text{ kip/ft})}$$

$$E = 14.292 \text{ ft}$$

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

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

$$a = \frac{(4 \times (16.508 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-1.155 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (16.508 \text{ kipft/ft})) + (4 \times (-1.155 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.5764 \text{ ft}$$

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

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

$$V_{max} = ((-1.155 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (14.292 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.5764 \text{ ft})}{(9.5 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (14.292 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.5764 \text{ ft})}{(9.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 15.345 \text{ kip}$$

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

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

$$M_{max} = ((-1.155 \text{ kip/ft}) \times (48 \text{ in}) \times (9.5 \text{ ft})) \times \left[ \left( \frac{(14.292 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.292 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (14.292 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 68.912 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.554 \text{ kip})}{(48 \text{ in})}$$

$$H_o = 0.1385 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(2.417 \text{ kipft}) + ((0.554 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.60425 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.60425 \text{ kipft/ft})}{(0.1385 \text{ kip/ft})}$$

$$E = 4.3628 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.60425 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (0.1385 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (0.60425 \text{ kipft/ft})) + (4 \times (0.1385 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.8021 \text{ ft}$$

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

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

$$V_{max} = ((0.1385 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.8021 \text{ ft})}{(9.5 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.8021 \text{ ft})}{(9.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.81979 \text{ kip}$$

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

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

$$M_{max} = ((0.1385 \text{ kip/ft}) \times (48 \text{ in}) \times (9.5 \text{ ft})) \times \left[ \left( \frac{(4.3628 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 3.4251 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 3 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.85$  - Alpha factor for axial strength,  
 $A_g = 1809.6 \text{ in}^2$  - 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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.453 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (3 \text{ ksi}) \times (1809.6 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1809.6 \text{ in}^2)) \right]$$

$$A_{st,required} = -79.896 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-79.896 \text{ in}^2), (0.0018 \times (1809.6 \text{ in}^2))]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(3.2572 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(3.2572 \text{ in}^2)}{(3.6816 \text{ in}^2)}$$

$$\text{Ratio} = 0.88474$$

Status: **PASS**  
Ratio: **0.880**

25.2.3

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

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

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

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

#### Ties:

25.7.2.2

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

25.7.2.1

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

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

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

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

#### Summary:

Main reinforcement: **12 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (3 \text{ ksi}) \times [(1809.6 \text{ in}^2) - (3.6816 \text{ in}^2)]) + ((60 \text{ ksi}) \times (3.6816 \text{ in}^2))]$$

$$\phi P_N = 2666.3 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(13.453 \text{ kip})}{(2666.3 \text{ kip})}$$

$$\text{Ratio} = 0.0050456$$

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

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

22.5.5.1.1

$V_{c,max}$  - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,max} = 324.49 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 13.453 \text{ kip} \rightarrow 13453 \text{ lbf}$ .

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(13453 \text{ lbf})}{6 \times (1809.6 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 132.08 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

22.5.5.1.2

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

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

$$V_{c,b} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + (0.05 \times (3000 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 406.27 \text{ kip}$$

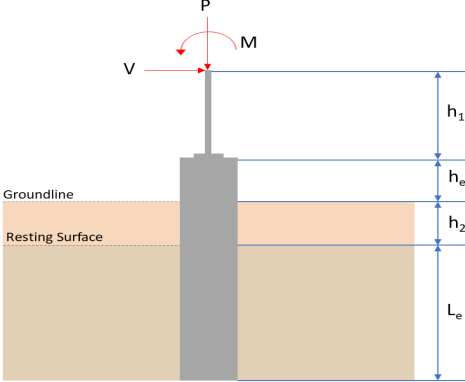
$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(324.49 \text{ kip}), (132.08 \text{ kip}), (406.27 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 132.08 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 807.65 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((132.08 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.93 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 15.345 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(15.345 \text{ kip})}{(118.93 \text{ kip})}$ $Ratio = 0.12903$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.81979 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.81979 \text{ kip})}{(118.93 \text{ kip})}$ $Ratio = 0.006893$	<p>Status: <b>PASS</b> Ratio: <b>0.130</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (48 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;"><math>S_m = 10857 \text{ in}^3</math></p> <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),          Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3 \text{ ksi}} \times 10857.344 \text{ in}^3$ $\phi M_{n,1} = 161.060 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times (10857 \text{ in}^3)$ $\phi M_{n,2} = 1499.7 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(161.06 \text{ kipft}), (1499.7 \text{ kipft})]$ $\phi M_n = 161.06 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 68.912 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(68.912 \text{ kipft})}{(161.06 \text{ kipft})}$ $\text{Ratio} = 0.42787$	<p>Status: <b>PASS</b>          Ratio: <b>0.430</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 3.4251 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.4251 \text{ kipft})}{(161.06 \text{ kipft})}$ $\text{Ratio} = 0.021266$	<p>Status: <b>PASS</b>          Ratio: <b>0.020</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: round <math>D = 48</math> in - Pile diameter <math>L = 9.5</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>7.938</td> <td>13.453</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-2.751</td> <td>-4.620</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.341</td> <td>-0.554</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-1.474</td> <td>-2.417</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>38.764</td> <td>66.032</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 3</math> ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure ( $q_a$ ) (psf)	Allowable Lateral Pressure ( $R$ ) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	$P$ (kip)	7.938	13.453	$V_x$ (kip)	-2.751	-4.620	$V_z$ (kip)	-0.341	-0.554	$M_x$ (kipft)	-1.474	-2.417	$M_z$ (kipft)	38.764	66.032	
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	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.751 \text{ kip})}{(48 \text{ in})}$ $H_o = -0.68775 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(38.764 \text{ kipft}) + ((-2.751 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 9.691 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.6839 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.341 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -0.08525 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.474 \text{ kipft}) + ((-0.341 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.3685 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.8579 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(8.6839 \text{ ft}), (2.8579 \text{ ft})]$$

$$L_{e,req} = 8.684 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (9.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9.5 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(8.684 \text{ ft})}{(9.5 \text{ ft})}$$

$$\text{Ratio} = 0.91411$$

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

### End-bearing Capacity (ASD)

$A$  - Pile cross-section area

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

$$A = \pi \times \left(\frac{(48 \text{ in})}{2}\right)^2$$

$$A = 12.566 \text{ ft}^2$$

$q$  - End-bearing pressure

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

$$q = \frac{(7.938 \text{ kip})}{(12.566 \text{ ft}^2)}$$

$$q = 0.63169 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.63169 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.31584$$

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

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(9.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.68775 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 9.691 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (9.691 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (9.691 \text{ kipft/ft})) + (4 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.5788 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.691 \text{ kipft/ft})) + (3 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]^2}{(9.5 \text{ ft})^2 \times [(3 \times (9.691 \text{ kipft/ft})) + (2 \times (-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = 0.29947 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (9.691 \text{ kipft/ft})) + ((-0.68775 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = 1.3418 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.5788 \text{ ft})}{2}$$

$$p_a = 0.49341 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.29947 \text{ kip/ft}^2)}{(0.49341 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.60694$$

Status: **PASS**  
Ratio: **0.610**

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9.5 \text{ ft})$$

$$p_s = 1.425 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.3418 \text{ kip/ft}^2)}{(1.425 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.9416$$

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

**Considering z-direction:**

$H_o = -0.08525 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 0.3685 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (0.3685 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-0.08525 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (0.3685 \text{ kipft/ft})) + (4 \times (-0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.8039 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.3685 \text{ kipft/ft})) + (3 \times (-0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]^2}{(9.5 \text{ ft})^2 \times [(3 \times (0.3685 \text{ kipft/ft})) + (2 \times (-0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]}$$

$$p = -0.023179 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (0.3685 \text{ kipft/ft})) + ((-0.08525 \text{ kip/ft}) \times (9.5 \text{ ft}))]}{(9.5 \text{ ft})^2}$$

$$s = -0.0076105 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.8039 \text{ ft})}{2}$$

$$p_a = 0.51029 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.023179 \text{ kip/ft}^2)}{(0.51029 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.045424$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9.5 \text{ ft})$$

$$p_s = 1.425 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

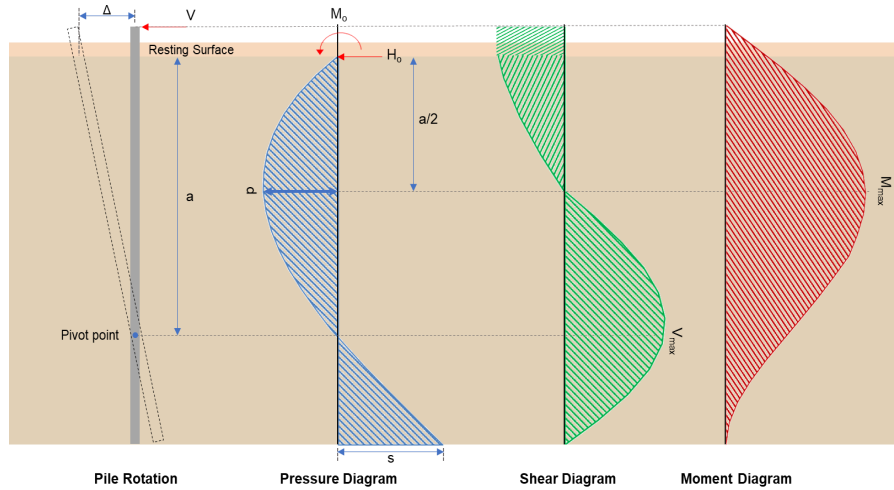
Status: **PASS**  
Ratio: **-0.050**

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

$$Ratio = \frac{(-0.0076105 \text{ kip/ft}^2)}{(1.425 \text{ kip/ft}^2)}$$

$$Ratio = -0.0053407$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-4.62 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -1.155 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(66.032 \text{ kipft}) + ((-4.62 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 16.508 \text{ kipft/ft}$$

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

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

$$E = \frac{(16.508 \text{ kipft/ft})}{(-1.155 \text{ kip/ft})}$$

$$E = 14.293 \text{ ft}$$

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

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

$$a = \frac{(4 \times (16.508 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-1.155 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (16.508 \text{ kipft/ft})) + (4 \times (-1.155 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.5764 \text{ ft}$$

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

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

$$V_{max} = ((-1.155 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (14.293 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.5764 \text{ ft})}{(9.5 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (14.293 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.5764 \text{ ft})}{(9.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 15.346 \text{ kip}$$

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

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

$$M_{max} = ((-1.155 \text{ kip/ft}) \times (48 \text{ in}) \times (9.5 \text{ ft})) \times \left[ \left( \frac{(14.293 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.293 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (14.293 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.5764 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 68.914 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.554 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -0.1385 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(2.417 \text{ kipft}) + ((-0.554 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 0.60425 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.60425 \text{ kipft/ft})}{(-0.1385 \text{ kip/ft})}$$

$$E = 4.3628 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.60425 \text{ kipft/ft}) \times (9.5 \text{ ft})) + (3 \times (-0.1385 \text{ kip/ft}) \times (9.5 \text{ ft})^2)}{(6 \times (0.60425 \text{ kipft/ft})) + (4 \times (-0.1385 \text{ kip/ft}) \times (9.5 \text{ ft}))}$$

$$a = 6.8021 \text{ ft}$$

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

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

$$V_{max} = ((-0.1385 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.8021 \text{ ft})}{(9.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.8021 \text{ ft})}{(9.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.81979 \text{ kip}$$

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

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

$$M_{max} = ((-0.1385 \text{ kip/ft}) \times (48 \text{ in}) \times (9.5 \text{ ft})) \times \left[ \left( \frac{(4.3628 \text{ ft})}{(9.5 \text{ ft})} + \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 3 \right) \times \left( \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (4.3628 \text{ ft})}{(9.5 \text{ ft})} + 2 \right) \times \left( \frac{(6.8021 \text{ ft})}{2 \times (9.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 3.4251 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 3 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.85$  - Alpha factor for axial strength,  
 $A_g = 1809.6 \text{ in}^2$  - 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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(13.453 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (3 \text{ ksi}) \times (1809.6 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1809.6 \text{ in}^2)) \right]$$

$$A_{st,required} = -79.896 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-79.896 \text{ in}^2), (0.0018 \times (1809.6 \text{ in}^2))]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(3.2572 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(3.2572 \text{ in}^2)}{(3.6816 \text{ in}^2)}$$

$$\text{Ratio} = 0.88474$$

Status: **PASS**  
Ratio: **0.880**

25.2.3

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

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

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

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

#### Ties:

25.7.2.2

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

25.7.2.1

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

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

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

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

#### Summary:

Main reinforcement: **12 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (3 \text{ ksi}) \times [(1809.6 \text{ in}^2) - (3.6816 \text{ in}^2)]) + ((60 \text{ ksi}) \times (3.6816 \text{ in}^2))]$$

$$\phi P_N = 2666.3 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(13.453 \text{ kip})}{(2666.3 \text{ kip})}$$

$$\text{Ratio} = 0.0050456$$

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

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

**Parameters:**

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

$$d = 0.80 D$$

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

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

22.5.5.1.3  $\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

22.5.5.1.1  $V_{c,max}$  - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,max} = 324.49 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 13.453 \text{ kip} \rightarrow 13453 \text{ lbf}$ .

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

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(13453 \text{ lbf})}{6 \times (1809.6 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 132.08 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

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

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

$$V_{c,b} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + (0.05 \times (3000 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 406.27 \text{ kip}$$

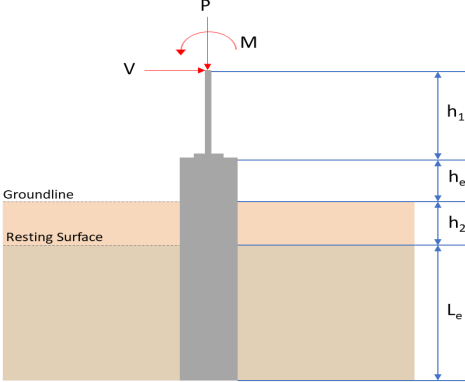
$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min}[(324.49 \text{ kip}), (132.08 \text{ kip}), (406.27 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 132.08 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 807.65 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((132.08 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.93 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 15.346 \text{ kip}</math> - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(15.346 \text{ kip})}{(118.93 \text{ kip})}$ $Ratio = 0.12903$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.81979 \text{ kip}</math> - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.81979 \text{ kip})}{(118.93 \text{ kip})}$ $Ratio = 0.006893$	<p>Status: <b>PASS</b> Ratio: <b>0.130</b></p> <p>Status: <b>PASS</b> Ratio: <b>0.010</b></p>
	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (48 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;"><math>S_m = 10857 \text{ in}^3</math></p> <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),          Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3 \text{ ksi}} \times 10857.344 \text{ in}^3$ $\phi M_{n,1} = 161.060 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times (10857 \text{ in}^3)$ $\phi M_{n,2} = 1499.7 \text{ kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(161.06 \text{ kipft}), (1499.7 \text{ kipft})]$ $\phi M_n = 161.06 \text{ kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 68.914 \text{ kipft}</math> - Maximum moment in the x-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(68.914 \text{ kipft})}{(161.06 \text{ kipft})}$ $\text{Ratio} = 0.42788$	<p>Status: <b>PASS</b>          Ratio: <b>0.430</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 3.4251 \text{ kipft}</math> - Maximum moment in the z-direction,          Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.4251 \text{ kipft})}{(161.06 \text{ kipft})}$ $\text{Ratio} = 0.021266$	<p>Status: <b>PASS</b>          Ratio: <b>0.020</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: round <math>D = 48</math> in - Pile diameter <math>L = 9.75</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resisting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (<math>q_a</math>) (psf)</th> <th>Allowable Lateral Pressure (<math>R</math>) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel &amp; clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p><b>Tabulation of Loads</b></p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>10.244</td> <td>17.491</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-3.248</td> <td>-5.439</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.000</td> <td>0.000</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>44.748</td> <td>77.112</td> </tr> </tbody> </table> <p><b>Material Properties</b> <math>f'_{ck} = 3</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)	10.244	17.491	$V_x$ (kip)	-3.248	-5.439	$V_z$ (kip)	0.000	0.000	$M_x$ (kipft)	0.000	0.000	$M_z$ (kipft)	44.748	77.112	
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$M_x$ (kipft)	0.000	0.000																										
$M_z$ (kipft)	44.748	77.112																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-3.248 \text{ kip})}{(48 \text{ in})}$ $H_o = -0.812 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{D}$																											

	$M_o = \frac{(44.748 \text{ kipft}) + ((-3.248 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$ $M_o = 11.187 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$ <p>Solving the cubic equation:  <math>L_{e,x} = 8.9621 \text{ ft}</math> - Required depth in x-direction,</p> <p><b>Considering z-direction:</b>  <math>L_{e,z} = 0 \text{ ft}</math> - Required depth in z-direction,</p> <p><b>Minimum embedded depth required:</b>  <math>L_{e,req}</math> - Depth of pile required,</p> $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(8.9621 \text{ ft}), (0 \text{ ft})]$ $L_{e,req} = 8.962 \text{ ft}$ <p><math>L_e</math> - Actual embedded length of pile,</p> $L_e = L - h_c - h_2$ $L_e = (9.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 9.75 \text{ ft}$ <p>Ratio - Embedded depth</p> $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(8.962 \text{ ft})}{(9.75 \text{ ft})}$ $\text{Ratio} = 0.91918$	<p>Status: <b>PASS</b>  Ratio: <b>0.920</b></p>
	<p><b>End-bearing Capacity (ASD)</b></p> <p>A - Pile cross-section area</p> $A = \pi \left(\frac{D}{2}\right)^2$ $A = \pi \times \left(\frac{(48 \text{ in})}{2}\right)^2$ $A = 12.566 \text{ ft}^2$ <p>q - End-bearing pressure</p> $q = \frac{P_c}{A}$ $q = \frac{(10.244 \text{ kip})}{(12.566 \text{ ft}^2)}$ $q = 0.81519 \text{ kip/ft}^2$ <p><b>Check bearing capacity ratio:</b></p> <p>Ratio - Capacity</p> $\text{Ratio} = \frac{q}{q_a}$ $\text{Ratio} = \frac{(0.81519 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.4076$	<p>Status: <b>PASS</b>  Ratio: <b>0.410</b></p>
Czerniak	<p><b>Lateral Soil Pressure (ASD):</b></p> <p>L/D - Length to least lateral dimension ratio,</p> $L/D = \frac{L}{D}$ $L/D = \frac{(9.75 \text{ ft})}{(48 \text{ in})}$	

$$L/D = 2.4375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.812$  kip/ft - Lateral force per length of pile,

$M_o = 11.187$  kipft/ft - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (11.187 \text{ kipft/ft}) \times (9.75 \text{ ft})) + (3 \times (-0.812 \text{ kip/ft}) \times (9.75 \text{ ft})^2)}{(6 \times (11.187 \text{ kipft/ft})) + (4 \times (-0.812 \text{ kip/ft}) \times (9.75 \text{ ft}))}$$

$$a = 6.7605 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.187 \text{ kipft/ft})) + (3 \times (-0.812 \text{ kip/ft}) \times (9.75 \text{ ft}))]^2}{(9.75 \text{ ft})^2 \times [(3 \times (11.187 \text{ kipft/ft})) + (2 \times (-0.812 \text{ kip/ft}) \times (9.75 \text{ ft}))]}$$

$$p = 0.30819 \text{ kip/ft}^2$$

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

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

$$s = \frac{9.425 \times [(2 \times (11.187 \text{ kipft/ft})) + ((-0.812 \text{ kip/ft}) \times (9.75 \text{ ft}))]}{(9.75 \text{ ft})^2}$$

$$s = 1.4333 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.7605 \text{ ft})}{2}$$

$$p_a = 0.50703 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.30819 \text{ kip/ft}^2)}{(0.50703 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.60782$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9.75 \text{ ft})$$

$$p_s = 1.4625 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

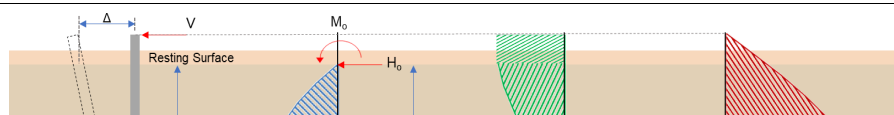
$$\text{Ratio} = \frac{s}{p_s}$$

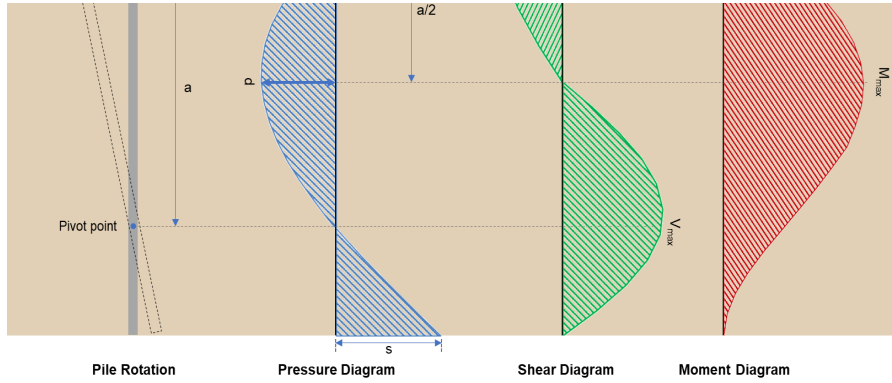
$$\text{Ratio} = \frac{(1.4333 \text{ kip/ft}^2)}{(1.4625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.98006$$

Status: **PASS**  
Ratio: **0.610**

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





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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-5.439 \text{ kip})}{(48 \text{ in})}$$

$$H_o = -1.3598 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(77.112 \text{ kipft}) + ((-5.439 \text{ kip}) \times (0 \text{ ft}))}{(48 \text{ in})}$$

$$M_o = 19.278 \text{ kipft/ft}$$

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

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

$$E = \frac{(19.278 \text{ kipft/ft})}{(-1.3598 \text{ kip/ft})}$$

$$E = 14.178 \text{ ft}$$

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

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

$$a = \frac{(4 \times (19.278 \text{ kipft/ft}) \times (9.75 \text{ ft})) + (3 \times (-1.3598 \text{ kip/ft}) \times (9.75 \text{ ft})^2)}{(6 \times (19.278 \text{ kipft/ft})) + (4 \times (-1.3598 \text{ kip/ft}) \times (9.75 \text{ ft}))}$$

$$a = 6.7554 \text{ ft}$$

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

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

$$V_{max} = ((-1.3598 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (14.178 \text{ ft})}{(9.75 \text{ ft})} + 3 \right) \times \left( \frac{(6.7554 \text{ ft})}{(9.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (14.178 \text{ ft})}{(9.75 \text{ ft})} + 2 \right) \times \left( \frac{(6.7554 \text{ ft})}{(9.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 17.581 \text{ kip}$$

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

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

$$M_{max} = ((-1.3598 \text{ kip/ft}) \times (48 \text{ in}) \times (9.75 \text{ ft})) \times \left[ \left( \frac{(14.178 \text{ ft})}{(9.75 \text{ ft})} + \frac{(6.7554 \text{ ft})}{2 \times (9.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.178 \text{ ft})}{(9.75 \text{ ft})} + 3 \right) \times \left( \frac{(6.7554 \text{ ft})}{2 \times (9.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (14.178 \text{ ft})}{(9.75 \text{ ft})} + 2 \right) \times \left( \frac{(6.7554 \text{ ft})}{2 \times (9.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 80.904 \text{ kipft}$$

### Minimum Reinforcement Check (LRFD)

#### Parameters:

$f'_{ck} = 3 \text{ ksi}$  - Concrete strength,  
 $f_{yk} = 60 \text{ ksi}$  - Longitudinal reinforcement strength,  
 $\phi = 0.65$  - Reduction factor for axial strength,  
 $\alpha = 0.85$  - Alpha factor for axial strength,  
 $A_g = 1809.6 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(17.491 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (3 \text{ ksi}) \times (1809.6 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1809.6 \text{ in}^2)) \right]$$

$$A_{st,required} = -79.769 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-79.769 \text{ in}^2), (0.0018 \times (1809.6 \text{ in}^2))]$$

$$A_{min} = 3.2572 \text{ in}^2$$

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

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

$$n_{rebar} = \frac{(3.2572 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 12$$

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

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

$$A_{st} = (12) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 3.6816 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(3.2572 \text{ in}^2)}{(3.6816 \text{ in}^2)}$$

$$\text{Ratio} = 0.88474$$

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. 10Ø: Use #3(0.375 in)

25.7.2.1

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

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

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

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

#### Summary:

Status: **PASS**  
Ratio: **0.880**

Main reinforcement: **12 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (3 \text{ ksi}) \times [(1809.6 \text{ in}^2) - (3.6816 \text{ in}^2)]) + ((60 \text{ ksi}) \times (3.6816 \text{ in}^2))]$$

$$\phi P_N = 2666.3 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(17,491 \text{ kip})}{(2666.3 \text{ kip})}$$

$$\text{Ratio} = 0.00656$$

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

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

**Parameters:**

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

$$d = 0.80 D$$

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

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

22.5.5.1.3  $\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

22.5.5.1.1  $V_{c,max}$  - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,max} = 324.49 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 17,491 \text{ kip} \rightarrow 17491 \text{ lbf}$ .

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

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(17491 \text{ lbf})}{6 \times (1809.6 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 132.76 \text{ kip}$$

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ .

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

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

$$V_{c,b} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + (0.05 \times (3000 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 406.27 \text{ kip}$$

$V_c$  - Governing shear strength of concrete

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

$$V_c = \text{Min} [(324.49 \text{ kip}), (132.76 \text{ kip}), (406.27 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;"><math>V_c = 132.76 \text{ kip}</math></p> <p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}</math>.</p> <p><math>V_{s,a}</math> - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 807.65 \text{ kip}$ <p><math>A_v</math> - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p><math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p><math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((132.76 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 119.38 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 17.581 \text{ kip}</math> - Maximum shear force in the x-direction,  <i>Ratio</i> - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(17.581 \text{ kip})}{(119.38 \text{ kip})}$ $\text{Ratio} = 0.14727$	<p>Status: <b>PASS</b>  Ratio: <b>0.150</b></p>
<p>14.5.2.1b</p>	<p><b>Flexural Strength (ACI 318-19, LFRD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (48 \text{ in})^3}{32}$ $S_m = 10857 \text{ in}^3$ <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:</p> <p><math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3 \text{ ksi})} \times 10857.344 \text{ in}^3$ $\phi M_{n,1} = 161.060 \text{ kipft}$ <p><math>\phi M_{n,2}</math></p>	

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times (10857 \text{ in}^3)$$

$$\phi M_{n,2} = 1499.7 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

$$\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$$

$$\phi M_n = \text{MIN}[(161.06 \text{ kipft}), (1499.7 \text{ kipft})]$$

$$\phi M_n = 161.06 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 80.904 \text{ kipft}$  - Maximum moment in the x-direction,

$Ratio$  - Capacity

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

$$Ratio = \frac{(80.904 \text{ kipft})}{(161.06 \text{ kipft})}$$

$$Ratio = 0.50233$$

Status: **PASS**  
Ratio: **0.500**