

# Your Project Calculations



Project Name: MTSOLAR\_04B8HD1C4096I

S3D Model Link:

[https://platform.skyciv.com/structural?preload\\_name=MTSOLAR\\_04B8HD1C4096I&preload\\_path=Shared%20Enterprise%20Folder/MT\\_Solar\\_Projects/5\\_2023](https://platform.skyciv.com/structural?preload_name=MTSOLAR_04B8HD1C4096I&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/5_2023)

Public Model Link:

[https://platform.skyciv.com/structural-viewer?project\\_id=bT27ie1MuxLEucq2GKRvza3OE00T2JF53vHpAK4pIKNUdnJg6EhkaAy1YDjvhl2V](https://platform.skyciv.com/structural-viewer?project_id=bT27ie1MuxLEucq2GKRvza3OE00T2JF53vHpAK4pIKNUdnJg6EhkaAy1YDjvhl2V)

## Array Specification

Product:	Beam
Unique ID:	3P-19.75-8TOP-HD-24-L-4Hx8W-D350
Duty Classification:	HD
Module Width:	39.45 in
Module Length:	79.06in
Number of Rows:	4
Number of Columns:	8
Total Number of Modules:	32
Desired Tilt Angle:	22
Front Edge Clearance:	8
Total Array Height at Tilt:	12.96 ft
Total Frame Length:	51.00 ft
Frame Weight:	2563 lbs
Array Dimensions N/S:	13.32 ft
Array Dimensions E/W:	53.37 ft
Rail Length:	159.80 in
Rail Spacing:	3.29 ft
Rail Check:	Not Checked

## Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	10.49 ft
Number of Poles:	3
Pole Spacing:	19.75 ft

## Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.50 ft Pile 2: 5.75 ft Pile 3: 5.50 ft
Foundation Volume:	9.926 y <sup>3</sup>
Foundation Result:	PASSED
Mount Twist:	0.554041 kip

## Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	611 Creek Ln, Flourtown, PA 19031, USA
Wind Speed:	105 mph
Snow Load:	30 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.015835 ksf



### Design Disclaimer

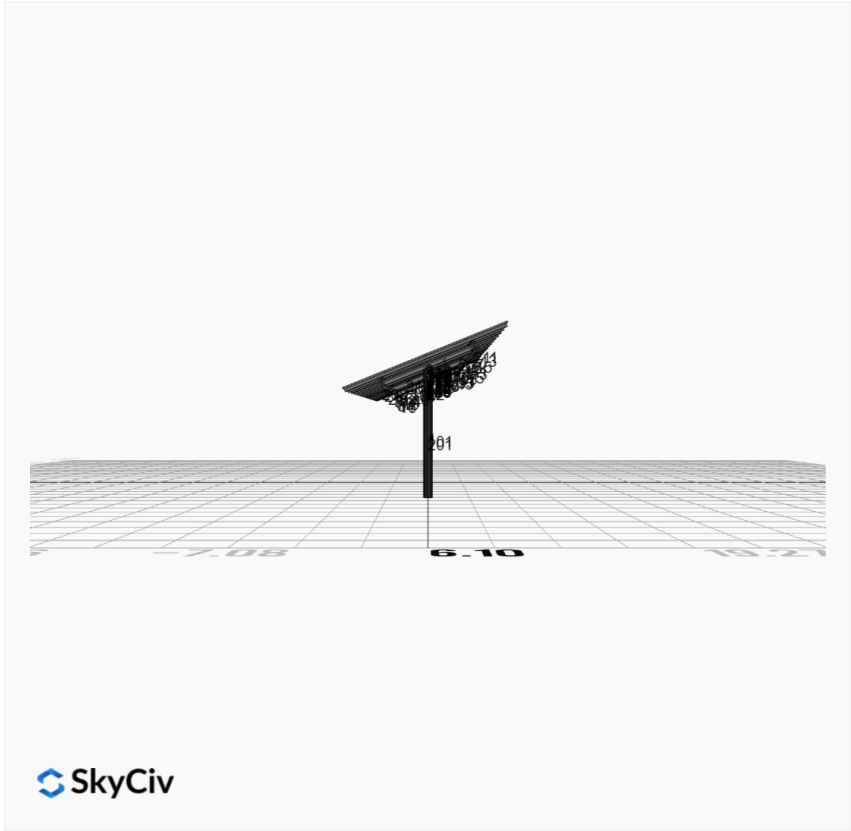
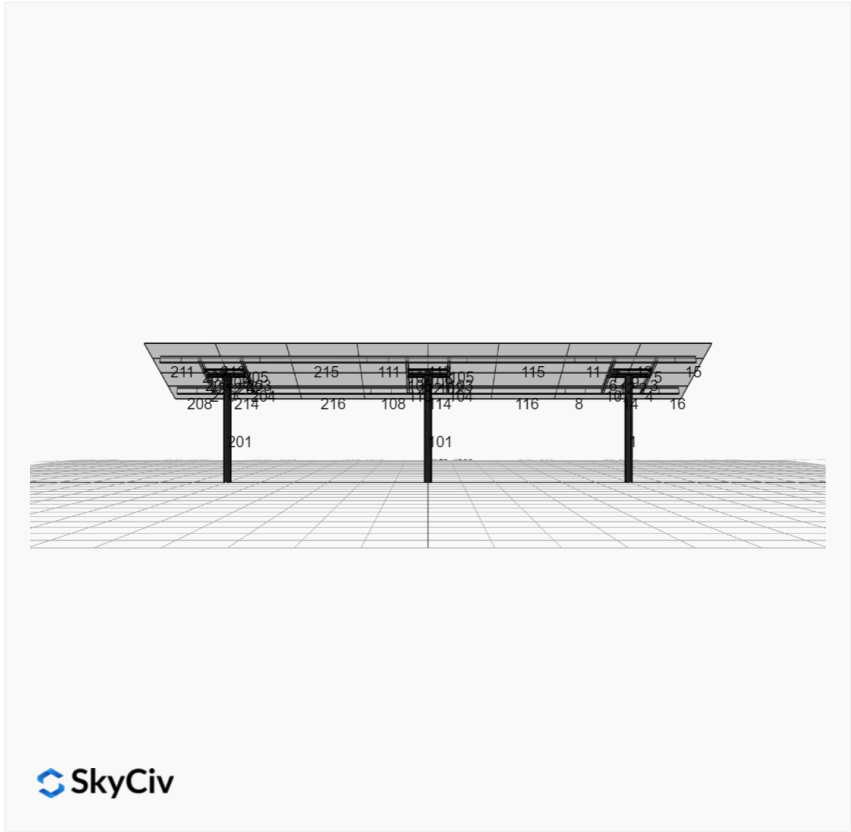
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

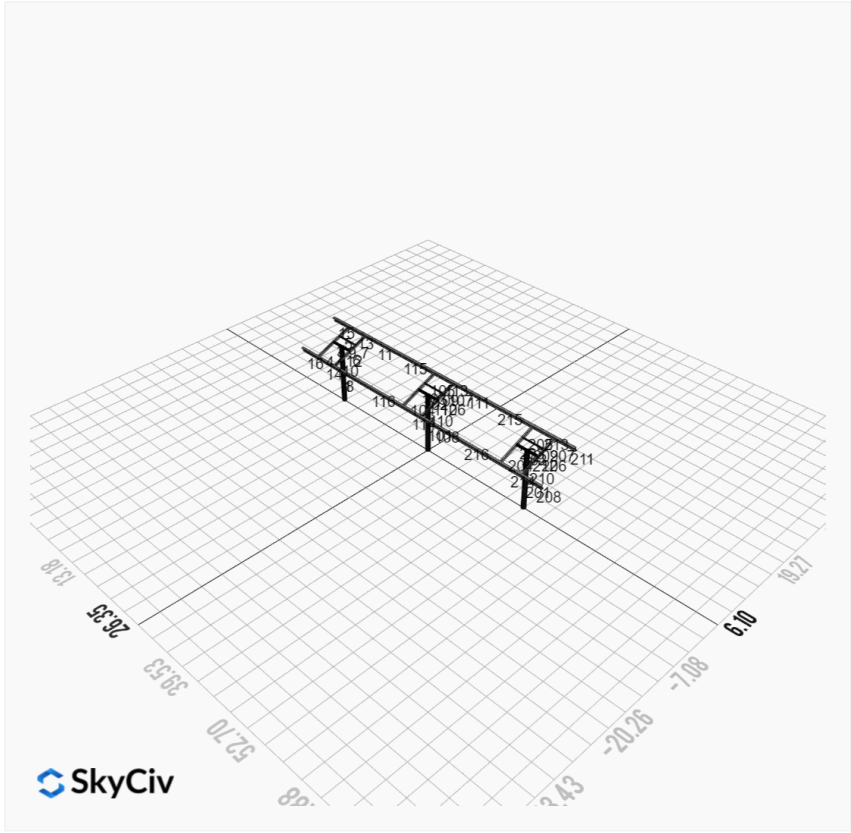
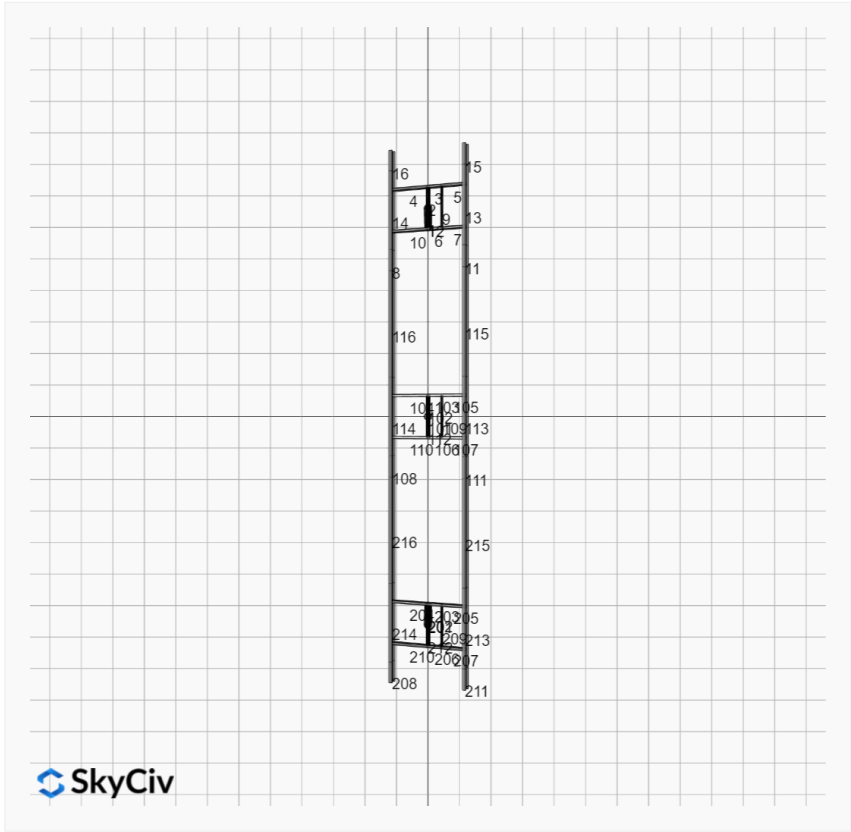
### AutoDesigner Input

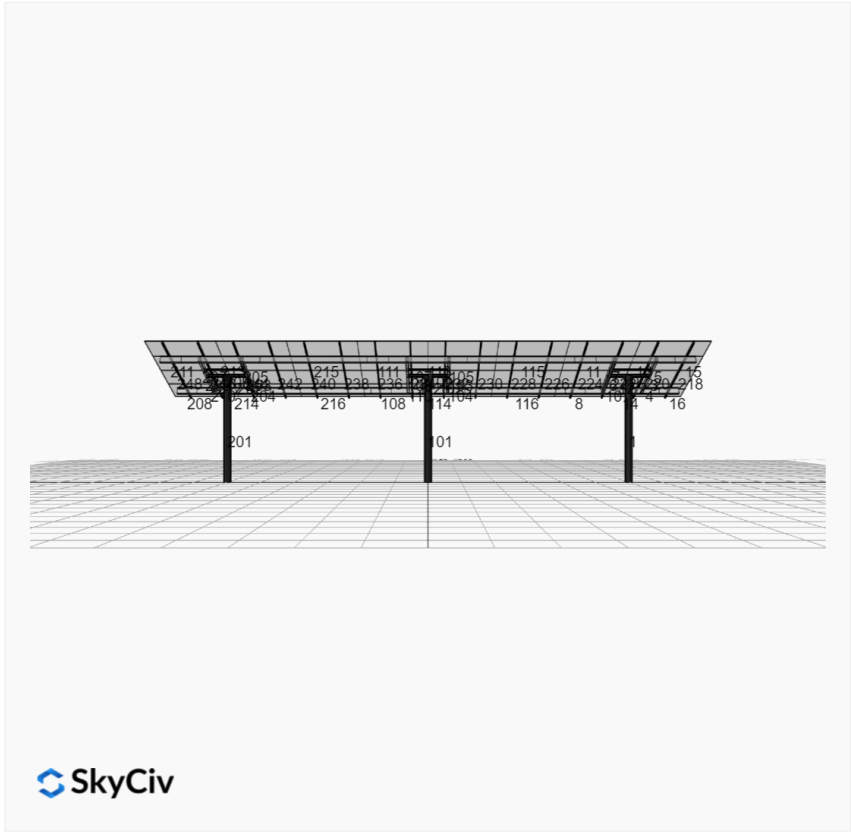
```
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"MTSOLAR_04B8HD1C4096I","site_address":"611 Creek Ln, Flourtown, PA 19031, USA","module_width":39.4488188976,"module_length":79.0551181102,"number_rows":4,"number_columns":8,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":15,"tilt_angle":22,"ground_clearance":8,"risk_category":"I","exposure_category":"B","frame_duty_override":"HD","pole_override":"8_40","soil_type":"sand","foundation_type":"Square","foundation_size":48,"check_rails":false}
```

### Design Notes:

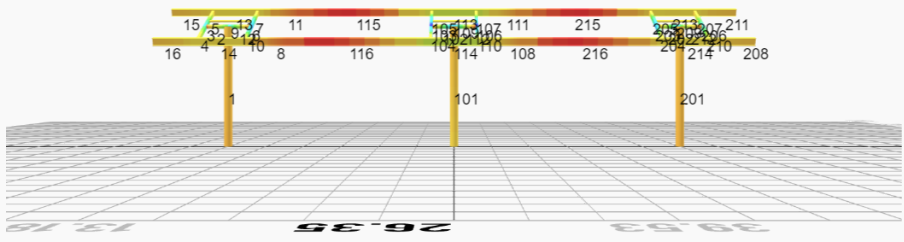
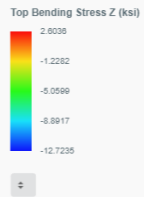
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



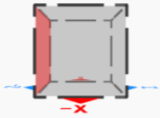


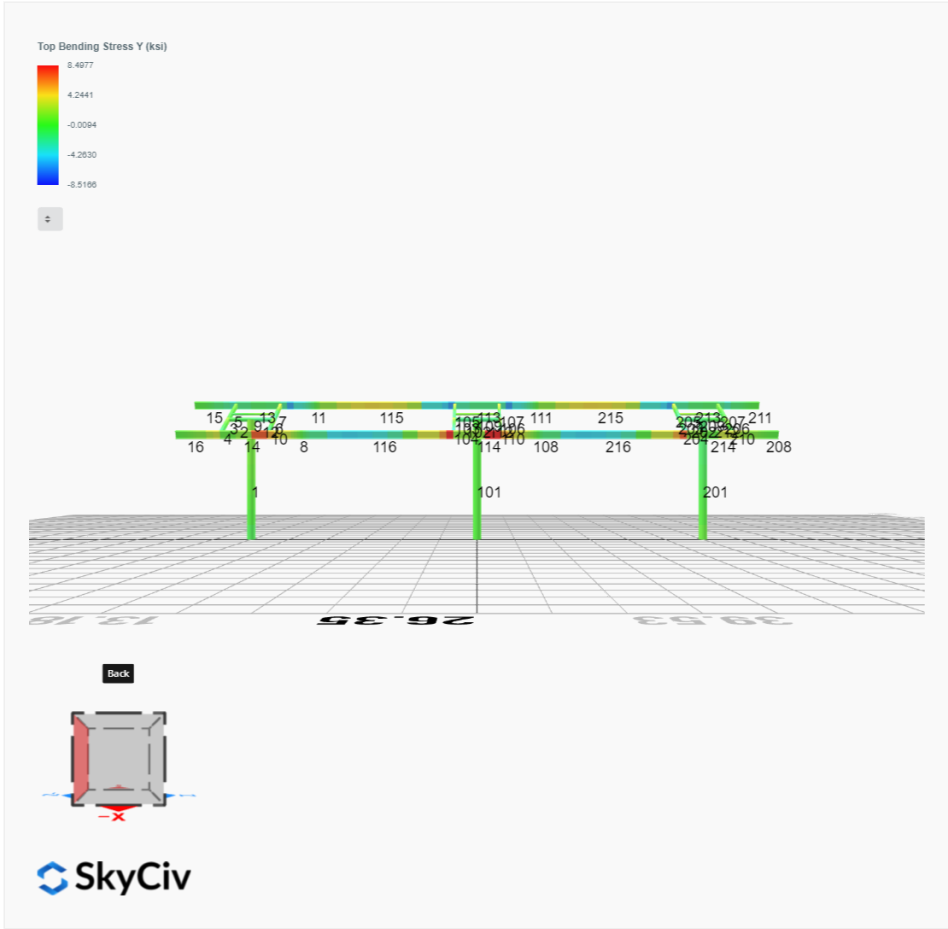


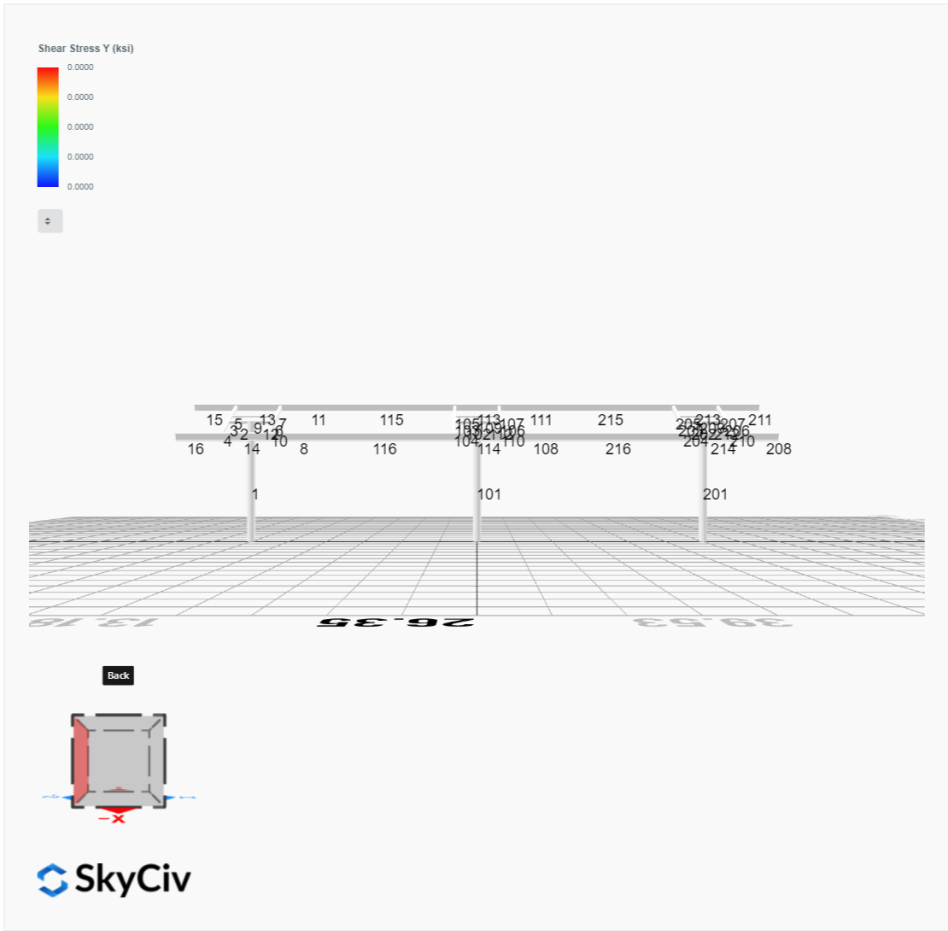


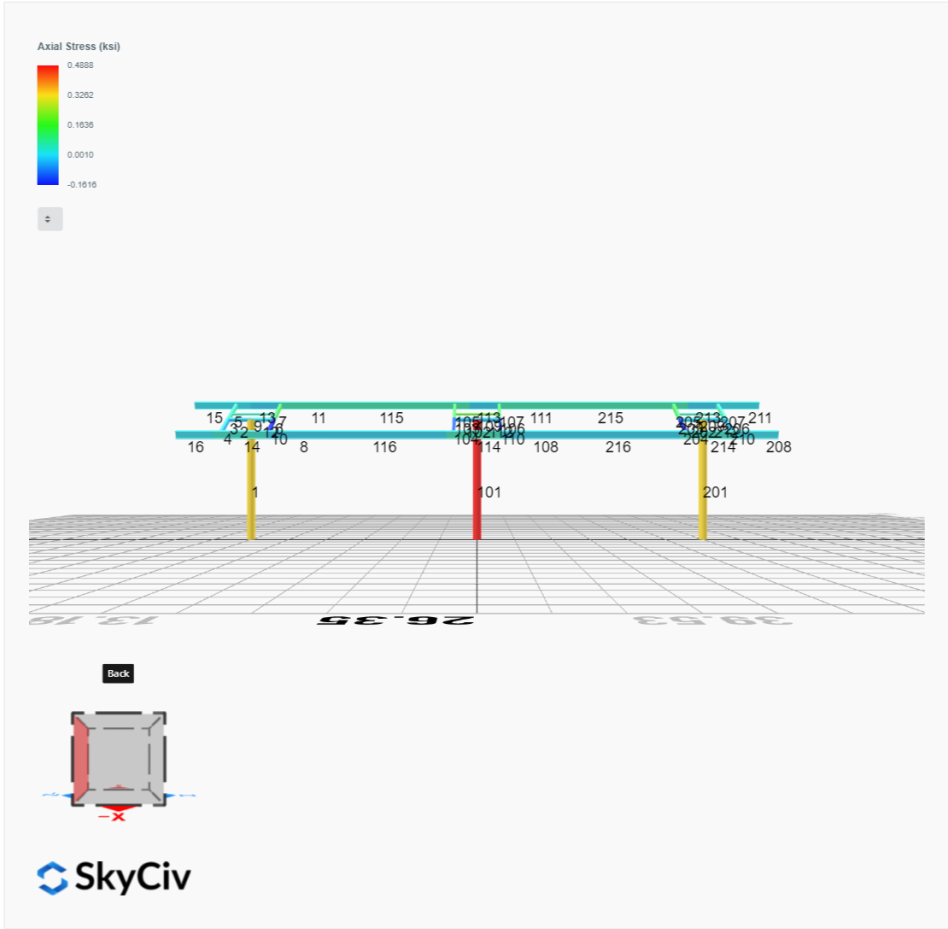


Back









## 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	0.0187	1.7913	0.0744	0.2192	-0.0417	-0.1502
ULS: 2. D + L	0.0187	1.7913	0.0744	0.2192	-0.0417	-0.1502
ULS: 3. D + (S or Lr or R)	0.0617	4.7238	0.2457	0.7241	-0.1381	-0.5512
ULS: 3. D + (S or Lr or R)	0.0187	1.7913	0.0744	0.2192	-0.0417	-0.1502
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0509	3.9907	0.2029	0.5979	-0.1140	-0.4510
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0187	1.7913	0.0744	0.2192	-0.0417	-0.1502
ULS: 5b. D + 0.7E	0.0187	1.7913	0.0744	0.2192	-0.0417	-0.1502
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0509	3.9907	0.2029	0.5979	-0.1140	-0.4510
ULS: 8. 0.6D + 0.7E	0.0112	1.0748	0.0447	0.1315	-0.0250	-0.0901
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.9429	4.1281	0.2327	0.6687	-0.3137	10.4818
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.9429	4.1281	0.2327	0.6687	-0.3137	10.4818
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.8611	-0.2600	-0.0617	-0.1672	0.1915	-8.6736
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.7692	-0.0075	-0.0596	-0.1601	0.1969	-13.8929
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6703	5.7433	0.3216	0.9350	-0.3180	7.5231
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6703	5.7433	0.3216	0.9350	-0.3180	7.5231
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6827	2.4523	0.1007	0.3081	0.0609	-6.8435
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.6138	2.6416	0.1024	0.3134	0.0650	-10.7580
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.7025	3.5439	0.1931	0.5563	-0.2457	7.8238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7025	3.5439	0.1931	0.5563	-0.2457	7.8238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6505	0.2528	-0.0277	-0.0706	0.1332	-6.5428
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5816	0.4422	-0.0261	-0.0653	0.1373	-10.4572
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.9504	3.4116	0.2029	0.5810	-0.2971	10.5419
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.9504	3.4116	0.2029	0.5810	-0.2971	10.5419
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.8536	-0.9765	-0.0915	-0.2549	0.2082	-8.6135
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.7618	-0.7240	-0.0894	-0.2478	0.2136	-13.8328

### 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	8.7895
Shear X	-1.6026
Shear Z	0.4974
Moment X	1.4540
Moment Y (Twist)	0.5538
Moment Z	23.5600

### 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	5.7433
Shear X	-0.9504
Shear Z	0.3216
Moment X	0.9350
Moment Y (Twist)	0.3180
Moment Z	13.8929

## 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	-0.0374	2.3027	0.0000	0.0000	0.0000	0.3841
ULS: 2. D + L	-0.0374	2.3027	0.0000	0.0000	0.0000	0.3841
ULS: 3. D + (S or Lr or R)	-0.1233	6.4085	0.0000	-0.0000	0.0001	1.2197
ULS: 3. D + (S or Lr or R)	-0.0374	2.3027	0.0000	0.0000	0.0000	0.3841
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1019	5.3820	0.0000	-0.0000	0.0000	1.0108
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0374	2.3027	0.0000	0.0000	0.0000	0.3841
ULS: 5b. D + 0.7E	-0.0374	2.3027	0.0000	0.0000	0.0000	0.3841

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1019	5.3820	0.0000	-0.0000	0.0000	1.0108
ULS: 8. 0.6D + 0.7E	-0.0225	1.3816	0.0000	0.0000	0.0000	0.2305
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3323	5.5940	0.0000	0.0000	0.0000	14.3538
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3323	5.5940	0.0000	0.0000	0.0000	14.3538
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.1052	-0.5930	0.0000	0.0000	0.0000	-10.8470
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.9231	-0.1925	0.0000	0.0000	0.0000	-16.9205
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0730	7.8505	0.0000	-0.0000	0.0000	11.4880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0730	7.8505	0.0000	-0.0000	0.0000	11.4880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.7551	3.2103	0.0000	-0.0000	0.0000	-7.4126
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.6186	3.5106	0.0000	-0.0000	0.0000	-11.9676
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0086	4.7712	0.0000	0.0000	0.0000	10.8614
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0086	4.7712	0.0000	0.0000	0.0000	10.8614
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.8195	0.1310	0.0000	0.0000	0.0000	-8.0392
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.6830	0.4313	0.0000	0.0000	0.0000	-12.5943
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.3174	4.6729	0.0000	-0.0000	0.0000	14.2001
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.3174	4.6729	0.0000	-0.0000	0.0000	14.2001
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.1202	-1.5141	0.0000	-0.0000	0.0000	-11.0007
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.9381	-1.1136	0.0000	0.0000	0.0000	-17.0741

#### Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	12.0742
Shear X	-2.2445
Shear Z	0.0000
Moment X	0.0001
Moment Y (Twist)	0.0003
Moment Z	28.8410

#### 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	7.8505
Shear X	-1.3323
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0001
Moment Z	17.0741

#### 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	0.0187	1.7913	-0.0744	-0.2192	0.0417	-0.1502
ULS: 2. D + L	0.0187	1.7913	-0.0744	-0.2192	0.0417	-0.1502
ULS: 3. D + (S or Lr or R)	0.0617	4.7238	-0.2457	-0.7242	0.1382	-0.5511
ULS: 3. D + (S or Lr or R)	0.0187	1.7913	-0.0744	-0.2192	0.0417	-0.1502
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0509	3.9907	-0.2029	-0.5979	0.1141	-0.4509
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0187	1.7913	-0.0744	-0.2192	0.0417	-0.1502
ULS: 5b. D + 0.7E	0.0187	1.7913	-0.0744	-0.2192	0.0417	-0.1502
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0509	3.9907	-0.2029	-0.5979	0.1141	-0.4509
ULS: 8. 0.6D + 0.7E	0.0112	1.0748	-0.0447	-0.1315	0.0250	-0.0901
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.9429	4.1281	-0.2327	-0.6687	0.3138	10.4819
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.9429	4.1281	-0.2327	-0.6687	0.3138	10.4819
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.8611	-0.2600	0.0617	0.1672	-0.1915	-8.6736
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.7692	-0.0075	0.0596	0.1601	-0.1969	-13.8929
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.6703	5.7433	-0.3216	-0.9350	0.3181	7.5232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.6703	5.7433	-0.3216	-0.9350	0.3181	7.5232
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6827	2.4522	-0.1007	-0.3081	-0.0608	-6.8434
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.6138	2.6416	-0.1024	-0.3134	-0.0649	-10.7579

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	-0.7025	3.5439	-0.1931	-0.5563	0.2458	7.8238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.7025	3.5439	-0.1931	-0.5563	0.2458	7.8238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6505	0.2528	0.0277	0.0706	-0.1332	-6.5428
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5816	0.4422	0.0261	0.0653	-0.1373	-10.4572
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.9504	3.4116	-0.2029	-0.5810	0.2971	10.5419
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.9504	3.4116	-0.2029	-0.5810	0.2971	10.5419
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.8536	-0.9765	0.0915	0.2549	-0.2082	-8.6135
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.7618	-0.7240	0.0894	0.2478	-0.2136	-13.8328

### 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	8.7895
Shear X	-1.6026
Shear Z	-0.4974
Moment X	-1.4542
Moment Y (Twist)	0.5540
Moment Z	23.5603

### 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	5.7433
Shear X	-0.9504
Shear Z	-0.3216
Moment X	-0.9350
Moment Y (Twist)	0.3181
Moment Z	13.8929

## Project Details

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

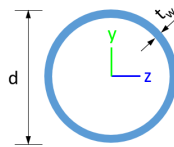


## Design Input Information

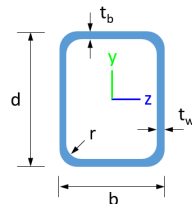
Design Factors			
$\Phi_t$	$\Phi_c$	$\Phi_b$	$\Phi_v$
0.9	0.9	0.9	0.9

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

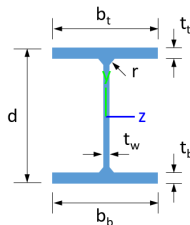
### Section Dimensions



ID	Name	d (in)	$t_w$ (in)				
2	2in Pipe Sch 80	2.38	0.22				
5	4in Pipe Sch 80	4.50	0.34				
9	8in Pipe Sch 40	8.63	0.32				



ID	Name	d (in)	b (in)	$t_w$ (in)	$t_b$ (in)	r (in)	
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17	



ID	Name	d (in)	$t_w$ (in)	$b_t$ (in)	$b_b$ (in)	$t_t$ (in)	$t_b$ (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

### Section Properties

ID	Name	A (in <sup>2</sup> )	J (in <sup>4</sup> )	$I_{yp}$ (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> )
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21



108	19	1.33	1.33	2.0 5	2.11,2.11,2.11,2.11,2.11,2.11,2.12,2.12,2.11,1.56,2.12,2.12,2.11,1.19,2.11,2.11,2.11,2.08,2.1 2,2.12,2.11,1.57,2.12,2.12,2.11,1.06	3 0 0	2 0 0	1
109	2	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
110	16	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.71,1.67,1.67,1.67,1.67,1.6 7,1.67,1.61,1.69,1.67,1.67,1.66,1.73	3 0 0	2 0 0	1
111	19	1.33	1.33	2.0 5	2.08,2.08,2.08,2.08,2.08,2.08,1.95,1.95,1.36,1.37,1.90,1.90,1.71,1.50,2.07,2.07,2.10,2.28,1.9 6,1.96,1.33,1.36,1.88,1.88,1.77,1.53	3 0 0	2 0 0	1
112	5	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
113	19	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.07,1.11,1.04,1.04,1.04,1.06,1.04,1.04,1.03,1.03,1.0 4,1.04,1.08,1.12,1.04,1.04,1.04,1.06	3 0 0	2 0 0	1
114	19	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.13,1.03,1.03,1.03,1.36,1.03,1.03,1.03,1.04,1.0 3,1.03,1.03,1.11,1.03,1.03,1.03,1.02	3 0 0	2 0 0	1
115	19	6.63	6.63	10. 20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.09,1.09,1.15,1.15,1.13,1.11,1.16,1.16,1.17,1.23,1.1 5,1.15,1.09,1.09,1.14,1.14,1.14,1.12	3 0 0	2 0 0	1
116	19	6.63	6.63	10. 20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.12,1.18,1.18,1.18,1.07,1.18,1.18,1.18,1.16,1.1 8,1.18,1.18,1.12,1.18,1.18,1.18,1.09	3 0 0	2 0 0	1
201	9	22.0 4	22.0 4	10. 49	-	3 0 0	2 0 0	1
202	5	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
203	16	0.92	0.92	1.4 2	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.17,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.19,1.1 9,1.19,1.14,1.17,1.19,1.19,1.18,1.18	3 0 0	2 0 0	1
204	16	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.65,1.71,1.67,1.67,1.68,1.67,1.6 8,1.68,1.60,1.70,1.67,1.67,1.66,1.74	3 0 0	2 0 0	1
205	16	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.6 7,1.67,1.62,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
206	16	0.92	0.92	1.4 2	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.13,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.18,1.1 8,1.18,1.08,1.15,1.17,1.17,1.16,1.17	3 0 0	2 0 0	1
207	16	1.52	1.52	2.3 3	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.63,1.66,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.68,1.6 7,1.67,1.58,1.65,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
208	19	4.20	4.20	2.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33,2.33,2.33	3 0 0	2 0 0	1
209	2	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
210	16	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.67,1.62,1.68,1.67,1.67,1.65,1.70,1.67,1.67,1.68,1.67,1.6 8,1.68,1.57,1.70,1.67,1.67,1.65,1.71	3 0 0	2 0 0	1
211	19	4.20	4.20	2.0 0	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.3 3,2.33,2.33,2.33,2.33,2.33,2.33,2.33	3 0 0	2 0 0	1
212	5	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
213	19	4.88	4.00	7.5 0	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.11,1.29,1.16,1.16,1.15,1.22,1.17,1.17,1.18,1.14,1.1 6,1.16,1.13,1.30,1.16,1.16,1.15,1.21	3 0 0	2 0 0	1
214	19	4.88	4.00	7.5 0	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.19,1.37,1.16,1.16,1.18,2.06,1.17,1.17,1.17,1.21,1.1 6,1.16,1.20,1.36,1.16,1.16,1.18,2.26	3 0 0	2 0 0	1
215	19	6.63	6.63	10. 20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.11,1.11,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.10,1.0 9,1.09,1.11,1.11,1.09,1.09,1.09,1.10	3 0 0	2 0 0	1
216	19	6.63	6.63	10. 20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.16,1.09,1.09,1.09,1.09,1.0 9,1.09,1.09,1.10,1.09,1.09,1.09,1.30	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	208.99	83.29	83.29	113.39	113.39
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	25.44	6.12	40.24	43.62
14	133.20	104.94	26.58	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	377.97	208.99	83.29	83.29	113.39	113.39
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.60	6.12	40.24	43.62
114	133.20	104.94	23.37	6.12	40.24	43.62
115	133.20	69.16	16.87	6.12	40.24	43.62
116	133.20	69.16	16.56	6.12	40.24	43.62
201	377.97	208.99	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	102.39	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	102.39	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	25.44	6.12	40.24	43.62
214	133.20	104.94	26.58	6.12	40.24	43.62
215	133.20	69.16	16.87	6.12	40.24	43.62
216	133.20	69.16	16.87	6.12	40.24	43.62

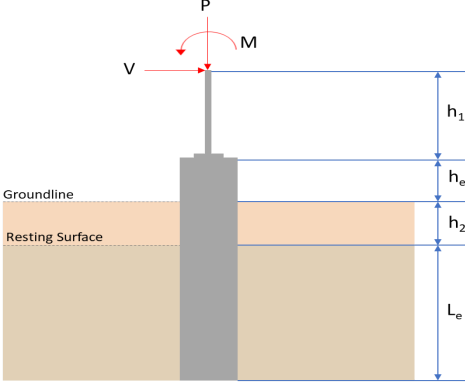
## Design Ratio

Member ID	P	M <sub>z</sub>	M <sub>y</sub>	V <sub>y</sub>	V <sub>z</sub>	(P,M <sub>z</sub> ,M <sub>y</sub> )	Worst LC	KL/r	φ	Status
1	0.042	0.283	0.045	0.014	0.004	0.286	#16	0.450	Not Required	Pass
2	0.002	0.237	0.063	0.057	0.012	0.284	#21	0.053	Not Required	Pass
3	0.004	0.397	0.014	0.039	0.003	0.400	#21	0.045	Not Required	Pass
4	0.003	0.387	0.057	0.039	0.014	0.445	#21	0.080	Not Required	Pass
5	0.004	0.246	0.032	0.040	0.008	0.248	#21	0.074	Not Required	Pass
6	0.007	0.563	0.074	0.058	0.020	0.641	#21	0.045	Not Required	Pass
7	0.007	0.348	0.114	0.056	0.028	0.379	#21	0.074	Not Required	Pass
8	0.002	0.104	0.098	0.035	0.011	0.152	#21	0.095	Not Required	Pass
9	0.004	0.059	0.060	0.003	0.004	0.121	#21	0.204	Not Required	Pass
10	0.008	0.539	0.097	0.054	0.020	0.583	#21	0.080	Not Required	Pass
11	0.004	0.104	0.103	0.036	0.011	0.148	#21	0.095	Not Required	Pass
12	0.001	0.409	0.088	0.085	0.016	0.474	#21	0.053	Not Required	Pass
13	0.005	0.096	0.260	0.048	0.014	0.318	#21	0.286	Not Required	Pass
14	0.003	0.091	0.254	0.046	0.014	0.303	#24	0.190	Not Required	Pass
15	0.000	0.016	0.025	0.013	0.004	0.042	#21	Not Required	Not Required	Pass
16	0.000	0.016	0.025	0.013	0.004	0.041	#21	Not Required	Not Required	Pass
101	0.058	0.344	0.000	0.020	0.000	0.347	#32	0.450	Not Required	Pass
102	0.002	0.457	0.111	0.098	0.019	0.548	#21	0.053	Not Required	Pass
103	0.007	0.666	0.041	0.067	0.006	0.709	#21	0.045	Not Required	Pass
104	0.007	0.664	0.114	0.067	0.024	0.742	#21	0.080	Not Required	Pass
105	0.007	0.413	0.118	0.066	0.030	0.444	#21	0.074	Not Required	Pass
106	0.007	0.666	0.041	0.067	0.006	0.709	#21	0.045	Not Required	Pass
107	0.007	0.413	0.118	0.066	0.030	0.444	#21	0.074	Not Required	Pass
108	0.002	0.053	0.111	0.045	0.011	0.153	#21	0.095	Not Required	Pass
109	0.010	0.063	0.033	0.001	0.000	0.101	#21	0.204	Not Required	Pass
110	0.007	0.664	0.114	0.067	0.024	0.742	#21	0.080	Not Required	Pass
111	0.004	0.066	0.111	0.044	0.011	0.142	#21	0.095	Not Required	Pass
112	0.002	0.457	0.111	0.098	0.019	0.548	#21	0.053	Not Required	Pass
113	0.005	0.208	0.271	0.056	0.014	0.460	#21	0.286	Not Required	Pass
114	0.005	0.232	0.271	0.056	0.014	0.481	#21	0.286	Not Required	Pass
115	0.007	0.280	0.141	0.044	0.011	0.425	#21	0.473	Not Required	Pass
116	0.003	0.262	0.143	0.045	0.011	0.405	#21	0.473	Not Required	Pass
201	0.042	0.283	0.045	0.014	0.004	0.286	#16	0.450	Not Required	Pass
202	0.001	0.409	0.088	0.085	0.016	0.474	#21	0.053	Not Required	Pass
203	0.007	0.563	0.074	0.058	0.020	0.641	#21	0.045	Not Required	Pass
204	0.008	0.539	0.097	0.054	0.020	0.583	#21	0.080	Not Required	Pass
205	0.007	0.348	0.114	0.056	0.028	0.379	#21	0.074	Not Required	Pass
206	0.004	0.397	0.014	0.039	0.003	0.400	#21	0.045	Not Required	Pass
207	0.004	0.246	0.032	0.040	0.008	0.248	#21	0.074	Not Required	Pass
208	0.000	0.016	0.025	0.013	0.004	0.041	#21	Not Required	Not Required	Pass
209	0.004	0.059	0.060	0.003	0.004	0.121	#21	0.204	Not Required	Pass
210	0.003	0.387	0.057	0.039	0.014	0.445	#21	0.080	Not Required	Pass
211	0.000	0.016	0.025	0.013	0.004	0.042	#21	Not Required	Not Required	Pass
212	0.002	0.238	0.063	0.057	0.012	0.284	#21	0.053	Not Required	Pass
213	0.005	0.096	0.260	0.048	0.014	0.318	#21	0.190	Not Required	Pass
214	0.003	0.091	0.254	0.046	0.014	0.303	#24	0.286	Not Required	Pass
215	0.007	0.297	0.142	0.036	0.011	0.437	#21	0.473	Not Required	Pass
216	0.003	0.286	0.142	0.035	0.011	0.424	#21	0.473	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: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 5.5</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" data-bbox="416 1102 1193 1191"> <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" data-bbox="676 1288 935 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>5.743</td> <td>8.789</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-0.950</td> <td>-1.603</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>0.322</td> <td>0.497</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>0.935</td> <td>1.454</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>13.893</td> <td>23.560</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)	5.743	8.789	$V_x$ (kip)	-0.950	-1.603	$V_z$ (kip)	0.322	0.497	$M_x$ (kipft)	0.935	1.454	$M_z$ (kipft)	13.893	23.560	
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)	5.743	8.789																										
$V_x$ (kip)	-0.950	-1.603																										
$V_z$ (kip)	0.322	0.497																										
$M_x$ (kipft)	0.935	1.454																										
$M_z$ (kipft)	13.893	23.560																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.95 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.15127 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(13.893 \text{ kipft}) + ((-0.95 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.2123 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.0774 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.322 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.051274 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.935 \text{ kipft}) + ((0.322 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.14889 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.7281 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.0774 \text{ ft}), (2.7281 \text{ ft})]$$

$$L_{e,req} = 5.077 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.077 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.92309$$

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

**End-bearing Capacity (ASD)**

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.743 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.35894 \text{ kip/ft}^2$$

$$q = 0.00094 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.35894 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.17947$$

Status: **PASS**  
Ratio: **0.180**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.15127 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 2.2123 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (2.2123 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.2123 \text{ kipft/ft})) + (4 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7585 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.2123 \text{ kipft/ft})) + (3 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.2123 \text{ kipft/ft})) + (2 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.20123 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (2.2123 \text{ kipft/ft})) + ((-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.71257 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7585 \text{ ft})}{2}$$

$$p_a = 0.28189 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20123 \text{ kip/ft}^2)}{(0.28189 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71387$$

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

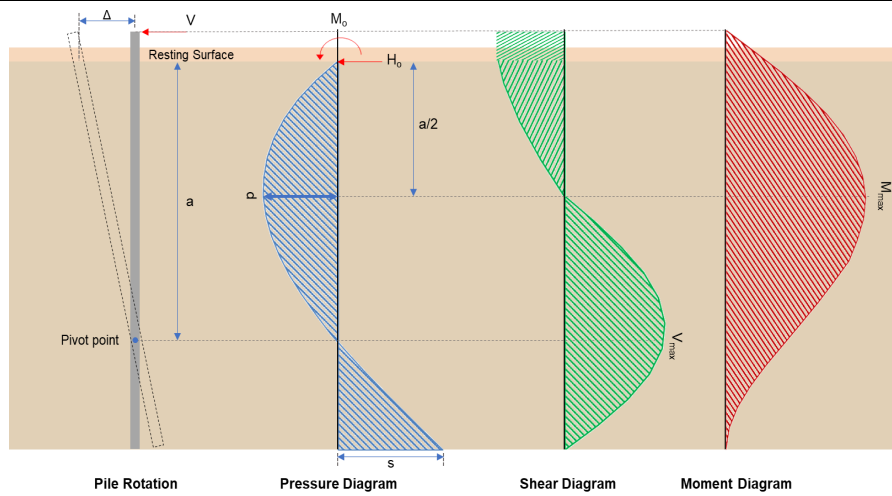
Status: **PASS**  
Ratio: **0.710**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.71257 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.86372$	Status: <b>PASS</b> Ratio: <b>0.860</b>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = 0.051274 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.14889 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.14889 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.051274 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.14889 \text{ kipft/ft})) + (4 \times (0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9224 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.14889 \text{ kipft/ft})) + (3 \times (0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.14889 \text{ kipft/ft})) + (2 \times (0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.050979 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.14889 \text{ kipft/ft})) + ((0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.115 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9224 \text{ ft})}{2}$ $p_a = 0.29418 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.050979 \text{ kip/ft}^2)}{(0.29418 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.17329$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: <b>PASS</b> Ratio: <b>0.170</b>

$$Ratio = \frac{(0.115 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.13939$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.603 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.25525 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.56 \text{ kipft}) + ((-1.603 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.7516 \text{ kipft/ft}$$

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

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

$$E = \frac{(3.7516 \text{ kipft/ft})}{(-0.25525 \text{ kip/ft})}$$

$$E = 14.697 \text{ ft}$$

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

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

$$a = \frac{(4 \times (3.7516 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.25525 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (3.7516 \text{ kipft/ft})) + (4 \times (-0.25525 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7582 \text{ ft}$$

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

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

$$V_{max} = ((-0.25525 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.7582 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.7582 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 5.5048 \text{ kip}$$

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

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

$$M_{max} = ((-0.25525 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(14.697 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 14.626 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(0.497 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.07914 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.454 \text{ kipft}) + ((0.497 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23153 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.23153 \text{ kipft/ft})}{(0.07914 \text{ kip/ft})}$$

$$E = 2.9256 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.23153 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.07914 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.23153 \text{ kipft/ft})) + (4 \times (0.07914 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9216 \text{ ft}$$

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

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

$$V_{max} = ((0.07914 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9216 \text{ ft})}{(5.5 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9216 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.50867 \text{ kip}$$

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

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

$$M_{max} = ((0.07914 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(2.9256 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.2434 \text{ kipft}$$

### 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,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(8.789 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -101.97 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-101.97 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

25.2.3

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

Main reinforcement: 14 - #5 (0.625 in)

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (3 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 3183.4 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(8.789 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0027609$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  
 $V_{c,max}$  - Max shear strength of concrete

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 8.789 \text{ kip} \rightarrow 8789 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(8789 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.97 \text{ kip}$$

22.5.5.1.2

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  
 $V_{c,b}$  - Shear strength of concrete (b)

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

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

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

$V_c$  - Governing shear strength of concrete

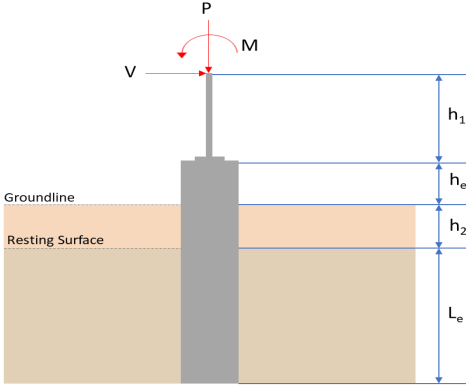
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.97 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.97 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}</math>,  <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>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.97 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.21 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 5.5048 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(5.5048 \text{ kip})}{(118.21 \text{ kip})}$ $\text{Ratio} = 0.046569$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.50867 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.50867 \text{ kip})}{(118.21 \text{ kip})}$ $\text{Ratio} = 0.0043032$	<p>Status: <b>PASS</b>  Ratio: <b>0.050</b></p> <p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LFRD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3\text{ksi}} \times 18432.001\text{in}^3$ $\phi M_{n,1} = 273.423\text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ksi}) \times (18432\text{in}^3)$ $\phi M_{n,2} = 2545.9\text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(273.42\text{kipft}), (2545.9\text{kipft})]$ $\phi M_n = 273.42\text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 14.626\text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(14.626\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.053491$	<p>Status: <b>PASS</b>  Ratio: <b>0.050</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 1.2434\text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.2434\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.0045476$	<p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 5.5</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" data-bbox="416 1099 1193 1193"> <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" data-bbox="676 1285 935 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>5.743</td> <td>8.789</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-0.950</td> <td>-1.603</td> </tr> <tr> <td><math>V_z</math> (kip)</td> <td>-0.322</td> <td>-0.497</td> </tr> <tr> <td><math>M_x</math> (kipft)</td> <td>-0.935</td> <td>-1.454</td> </tr> <tr> <td><math>M_z</math> (kipft)</td> <td>13.893</td> <td>23.560</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)	5.743	8.789	$V_x$ (kip)	-0.950	-1.603	$V_z$ (kip)	-0.322	-0.497	$M_x$ (kipft)	-0.935	-1.454	$M_z$ (kipft)	13.893	23.560	
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)	5.743	8.789																										
$V_x$ (kip)	-0.950	-1.603																										
$V_z$ (kip)	-0.322	-0.497																										
$M_x$ (kipft)	-0.935	-1.454																										
$M_z$ (kipft)	13.893	23.560																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.95 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.15127 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(13.893 \text{ kipft}) + ((-0.95 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.2123 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 5.0774 \text{ ft}$  - Required depth in x-direction,

**Considering z-direction:**

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.322 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.051274 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(0.935 \text{ kipft}) + ((-0.322 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.14889 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.8416 \text{ ft}$  - Required depth in z-direction,

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.0774 \text{ ft}), (1.8416 \text{ ft})]$$

$$L_{e,req} = 5.077 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.077 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.92309$$

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

**End-bearing Capacity (ASD)**

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.743 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.35894 \text{ kip/ft}^2$$

$$q = 0.35894 \text{ kip/ft}$$

**Check bearing capacity ratio:**

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.35894 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.17947$$

Status: **PASS**  
Ratio: **0.180**

Czerniak

**Lateral Soil Pressure (ASD):**

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

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.15127 \text{ kip/ft}$  - Lateral force per length of pile,

$M_o = 2.2123 \text{ kipft/ft}$  - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (2.2123 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.2123 \text{ kipft/ft})) + (4 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7585 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.2123 \text{ kipft/ft})) + (3 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.2123 \text{ kipft/ft})) + (2 \times (-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.20123 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 \times [(2 \times (2.2123 \text{ kipft/ft})) + ((-0.15127 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.71257 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7585 \text{ ft})}{2}$$

$$p_a = 0.28189 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20123 \text{ kip/ft}^2)}{(0.28189 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.71387$$

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

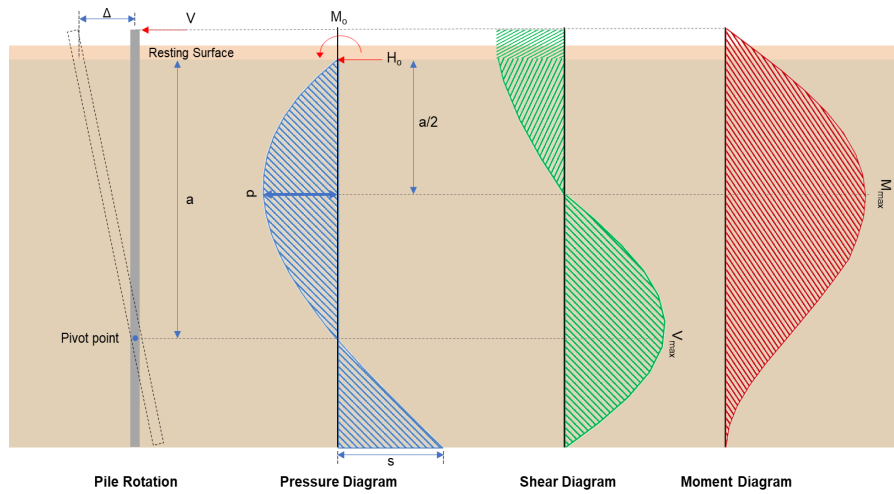
Status: **PASS**  
Ratio: **0.710**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.71257 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.86372$	Status: <b>PASS</b> Ratio: <b>0.860</b>
	<p><b>Considering z-direction:</b></p> <p><math>H_o = -0.051274 \text{ kip/ft}</math> - Lateral force per length of pile,  <math>M_o = 0.14889 \text{ kipft/ft}</math> - Overturning moment per length of pile,  <math>a</math> - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.14889 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.051274 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.14889 \text{ kipft/ft})) + (4 \times (-0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9224 \text{ ft}$ <p><math>p</math> - Earth pressure against the pile at distance <math>a/2</math> from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.14889 \text{ kipft/ft})) + (3 \times (-0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.14889 \text{ kipft/ft})) + (2 \times (-0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = -0.013255 \text{ kip/ft}^2$ <p><math>s</math> - Earth pressure against the pile at distance <math>L_e</math>,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.14889 \text{ kipft/ft})) + ((-0.051274 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.0031268 \text{ kip/ft}^2$ <p><b>Check lateral soil pressure capacity:</b></p> <p><math>p_a</math> - Allowable lateral soil pressure at depth <math>a/2</math>,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9224 \text{ ft})}{2}$ $p_a = 0.29418 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.013255 \text{ kip/ft}^2)}{(0.29418 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.045056$ <p><math>p_s</math> - Allowable lateral soil pressure at depth <math>L_e</math>,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: <b>PASS</b> Ratio: <b>-0.050</b>

$$Ratio = \frac{(0.0031268 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.0037901$$

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



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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-1.603 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.25525 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(23.56 \text{ kipft}) + ((-1.603 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.7516 \text{ kipft/ft}$$

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

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

$$E = \frac{(3.7516 \text{ kipft/ft})}{(-0.25525 \text{ kip/ft})}$$

$$E = 14.697 \text{ ft}$$

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

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

$$a = \frac{(4 \times (3.7516 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.25525 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (3.7516 \text{ kipft/ft})) + (4 \times (-0.25525 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7582 \text{ ft}$$

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

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

$$V_{max} = ((-0.25525 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.7582 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.7582 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 5.5048 \text{ kip}$$

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

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

$$M_{max} = ((-0.25525 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(14.697 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (14.697 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.7582 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 14.626 \text{ kipft}$$

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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-0.497 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.07914 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

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

$$M_o = \frac{(1.454 \text{ kipft}) + ((-0.497 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.23153 \text{ kipft/ft}$$

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

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

$$E = \frac{(0.23153 \text{ kipft/ft})}{(-0.07914 \text{ kip/ft})}$$

$$E = 2.9256 \text{ ft}$$

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

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

$$a = \frac{(4 \times (0.23153 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.07914 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.23153 \text{ kipft/ft})) + (4 \times (-0.07914 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9216 \text{ ft}$$

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

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

$$V_{max} = ((-0.07914 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9216 \text{ ft})}{(5.5 \text{ ft})} \right)^2 + 4 \times \left( \frac{3 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9216 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.50867 \text{ kip}$$

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

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

$$M_{max} = ((-0.07914 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[ \left( \frac{(2.9256 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[ \left( \frac{4 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left( \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 + \left[ \left( \frac{3 \times (2.9256 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left( \frac{(3.9216 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 1.2434 \text{ kipft}$$

### 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,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(8.789 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -101.97 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-101.97 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

25.2.3

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

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

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

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

#### Ties:

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

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

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

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

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

#### Summary:

Main reinforcement: 14 - #5 (0.625 in)

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

Ties: #3(0.375 in) - 10 in

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

22.4.2.2

$\phi P_N$  - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (3 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 3183.4 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(8.789 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0027609$$

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

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

**Parameters:**

22.5.2.2

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

$$d = 0.80 D$$

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

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

22.5.5.1.3

$\lambda_s$  - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  
 $V_{c,max}$  - Max shear strength of concrete

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

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

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

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 8.789 \text{ kip} \rightarrow 8789 \text{ lbf}$ ,  
 $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(8789 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.97 \text{ kip}$$

22.5.5.1.2

The following variables were converted to be consistent with empirical formula  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  
 $V_{c,b}$  - Shear strength of concrete (b)

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

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

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

$V_c$  - Governing shear strength of concrete

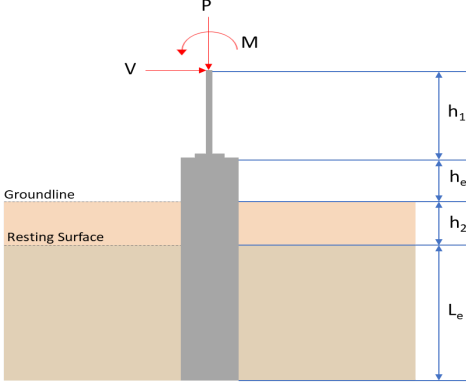
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.97 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.97 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula <math>f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}</math>,  <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>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p><math>V_s</math> - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.97 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.21 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 5.5048 \text{ kip}</math> - Maximum shear force in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(5.5048 \text{ kip})}{(118.21 \text{ kip})}$ $\text{Ratio} = 0.046569$ <p><b>Considering z-direction:</b></p> <p><math>V_{max} = 0.50867 \text{ kip}</math> - Maximum shear force in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.50867 \text{ kip})}{(118.21 \text{ kip})}$ $\text{Ratio} = 0.0043032$	<p>Status: <b>PASS</b>  Ratio: <b>0.050</b></p> <p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>
	<p><b>Flexural Strength (ACI 318-19, LFRD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:  <math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3\text{ksi}} \times 18432.001\text{in}^3$ $\phi M_{n,1} = 273.423\text{kipft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ksi}) \times (18432\text{in}^3)$ $\phi M_{n,2} = 2545.9\text{kipft}$ <p>Therefore,  <math>\phi M_n</math> - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(273.42\text{kipft}), (2545.9\text{kipft})]$ $\phi M_n = 273.42\text{kipft}$ <p><b>Considering x-direction:</b>  <math>M_{max} = 14.626\text{kipft}</math> - Maximum moment in the x-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(14.626\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.053491$	<p>Status: <b>PASS</b>  Ratio: <b>0.050</b></p>
	<p><b>Considering z-direction:</b>  <math>M_{max} = 1.2434\text{kipft}</math> - Maximum moment in the z-direction,  Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.2434\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.0045476$	<p>Status: <b>PASS</b>  Ratio: <b>0.000</b></p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p><b>SkyCiv Foundation Design</b> Pile Foundation</p> <p><b>Design Information :</b> Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p><b>Pile Input</b></p>  <p><b>Geometry</b> Pile shape: rectangular <math>b = 48</math> in - Pile width <math>D = 48</math> in - Pile depth <math>L = 5.75</math> ft - Total pile length <math>h_1 = 0</math> ft - Lateral load height from the top of the pile, <math>h_2 = 0</math> ft - Depth to resting surface <math>h_e = 0</math> ft - Length of pile above the ground</p> <p><b>Tabulation of Soil Parameters</b></p> <table border="1" data-bbox="416 1102 1193 1191"> <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" data-bbox="676 1288 933 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td><math>P</math> (kip)</td> <td>7.850</td> <td>12.074</td> </tr> <tr> <td><math>V_x</math> (kip)</td> <td>-1.332</td> <td>-2.245</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>17.074</td> <td>28.841</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)	7.850	12.074	$V_x$ (kip)	-1.332	-2.245	$V_z$ (kip)	0.000	0.000	$M_x$ (kipft)	0.000	0.000	$M_z$ (kipft)	17.074	28.841	
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)	7.850	12.074																										
$V_x$ (kip)	-1.332	-2.245																										
$V_z$ (kip)	0.000	0.000																										
$M_x$ (kipft)	0.000	0.000																										
$M_z$ (kipft)	17.074	28.841																										
	<p><b>Required depth to resist lateral loads (ASD)</b> <math>H</math> - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p><b>Considering x-direction:</b> <math>H_o</math> - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.332 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.2121 \text{ kip/ft}$ <p><math>M_o</math> - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(17.074 \text{ kipft}) + ((-1.332 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.7188 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$$L_{e,x} = 5.3121 \text{ ft} - \text{Required depth in x-direction,}$$

**Considering z-direction:**

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

**Minimum embedded depth required:**

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

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

$$L_{e,req} = \text{MAX}[(5.3121 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.312 \text{ ft}$$

$L_e$  - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.75 \text{ ft}$$

**Ratio** - Embedded depth

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

$$\text{Ratio} = \frac{(5.312 \text{ ft})}{(5.75 \text{ ft})}$$

$$\text{Ratio} = 0.92383$$

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

### End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.85 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.49062 \text{ kip/ft}^2$$

**Check bearing capacity ratio:**

**Ratio** - Capacity

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

$$\text{Ratio} = \frac{(0.49062 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.24531$$

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

Czerniak

### Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.4375$$

Since  $L/D \leq 10$ ,

Pile is short.

**Considering x-direction:**

$H_o = -0.2121$  kip/ft - Lateral force per length of pile,

$M_o = 2.7188$  kipft/ft - Overturning moment per length of pile,

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

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

$$a = \frac{(4 \times (2.7188 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.2121 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (2.7188 \text{ kipft/ft})) + (4 \times (-0.2121 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9436 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (2.7188 \text{ kipft/ft})) + (3 \times (-0.2121 \text{ kip/ft}) \times (5.75 \text{ ft}))]^2}{(5.75 \text{ ft})^2 [(3 \times (2.7188 \text{ kipft/ft})) + (2 \times (-0.2121 \text{ kip/ft}) \times (5.75 \text{ ft}))]}$$

$$p = 0.20663 \text{ kip/ft}^2$$

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

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

$$s = \frac{6 [(2 \times (2.7188 \text{ kipft/ft})) + ((-0.2121 \text{ kip/ft}) \times (5.75 \text{ ft}))]}{(5.75 \text{ ft})^2}$$

$$s = 0.76546 \text{ kip/ft}^2$$

**Check lateral soil pressure capacity:**

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9436 \text{ ft})}{2}$$

$$p_a = 0.29577 \text{ kip/ft}^2$$

*Ratio* - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.20663 \text{ kip/ft}^2)}{(0.29577 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.69859$$

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

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.75 \text{ ft})$$

$$p_s = 0.8625 \text{ kip/ft}^2$$

*Ratio* - Lateral soil capacity

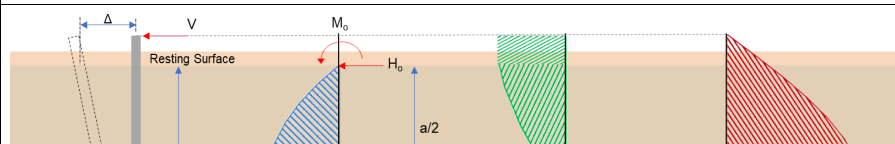
$$\text{Ratio} = \frac{s}{p_s}$$

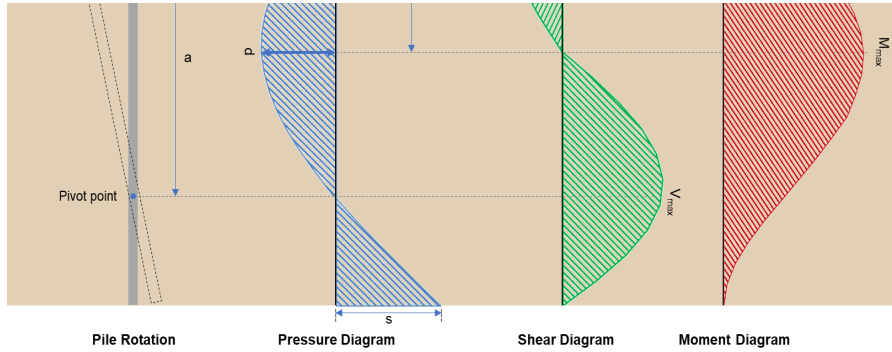
$$\text{Ratio} = \frac{(0.76546 \text{ kip/ft}^2)}{(0.8625 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.88749$$

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

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





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

$H_o$  - Lateral force per length of pile,

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

$$H_o = \frac{(-2.245 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.35748 \text{ kip/ft}$$

$M_o$  - Moment per length of pile,

$$M_o = \frac{M_e + (V_e H)}{1.57 D}$$

$$M_o = \frac{(28.841 \text{ kipft}) + ((-2.245 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.5925 \text{ kipft/ft}$$

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

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

$$E = \frac{(4.5925 \text{ kipft/ft})}{(-0.35748 \text{ kip/ft})}$$

$$E = 12.847 \text{ ft}$$

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

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

$$a = \frac{(4 \times (4.5925 \text{ kipft/ft}) \times (5.75 \text{ ft})) + (3 \times (-0.35748 \text{ kip/ft}) \times (5.75 \text{ ft})^2)}{(6 \times (4.5925 \text{ kipft/ft})) + (4 \times (-0.35748 \text{ kip/ft}) \times (5.75 \text{ ft}))}$$

$$a = 3.9435 \text{ ft}$$

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

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

$$V_{max} = ((-0.35748 \text{ kip/ft}) \times (48 \text{ in})) \times \left[ 1 - \left[ 3 \times \left( \frac{4 \times (12.847 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9435 \text{ ft})}{(5.75 \text{ ft})} \right)^2 \right] + \left[ 4 \times \left( \frac{3 \times (12.847 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9435 \text{ ft})}{(5.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 6.5984 \text{ kip}$$

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

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

$$M_{max} = ((-0.35748 \text{ kip/ft}) \times (48 \text{ in}) \times (5.75 \text{ ft})) \times \left[ \left( \frac{(12.847 \text{ ft})}{(5.75 \text{ ft})} + \frac{(3.9435 \text{ ft})}{2 \times (5.75 \text{ ft})} \right) - \left[ \left( \frac{4 \times (12.847 \text{ ft})}{(5.75 \text{ ft})} + 3 \right) \times \left( \frac{(3.9435 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^3 \right] + \left[ \left( \frac{3 \times (12.847 \text{ ft})}{(5.75 \text{ ft})} + 2 \right) \times \left( \frac{(3.9435 \text{ ft})}{2 \times (5.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 18.221 \text{ kipft}$$

### 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,  
 $\alpha = 0.8$  - Alpha factor for axial strength,  
 $A_g = 2304 \text{ in}^2$  - Gross area of concrete,

Table 22.4.2.1

#### Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[ \frac{\frac{(12.074 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -101.86 \text{ in}^2$$

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

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

$$A_{min} = \text{Max} [(-101.86 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$n_{rebar} = 14$$

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

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

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

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

Ratio - Capacity

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

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

$$\text{Ratio} = 0.96556$$

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

25.2.3

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

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

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

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

#### Ties:

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

25.7.2.1

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

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

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

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

#### Summary:

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (3 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 3183.4 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(12.074 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0037928$$

Status: **PASS**  
Ratio: **0.000****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  $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$ ,  $P = 12.074 \text{ kip} \rightarrow 12074 \text{ lbf}$ ,22.5.5.1.1(a)  $V_{c,a}$  - Shear strength of concrete (a)

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

$$V_{c,a} = \left[ 2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(12074 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 131.4 \text{ kip}$$

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

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

$$V_c = \text{Min}[(324.49 \text{ kip}), (131.4 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 131.4 \text{ kip}$$

<p>22.5.1.2</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>22.5.8.5.3 <math>V_{s,b}</math> - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{ywk} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <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>22.5.1.1 <math>\phi V_n</math> - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((131.4 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.49 \text{ kip}$ <p><b>Considering x-direction:</b></p> <p><math>V_{max} = 6.5984 \text{ kip}</math> - Maximum shear force in the x-direction,  <b>Ratio</b> - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(6.5984 \text{ kip})}{(118.49 \text{ kip})}$ $\text{Ratio} = 0.055686$	<p>Status: <b>PASS</b>  Ratio: <b>0.060</b></p>
<p>14.5.2.1b</p>	<p><b>Flexural Strength (ACI 318-19, LRFD)</b></p> <p><math>S_m</math> - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p><math>\lambda = 1</math> - Concrete modification factor (Normal concrete),  Allowable flexural strength:  <math>M_n</math> shall be the lesser of:</p> <p><math>\phi M_{n,1}</math></p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 273.423 \text{ kip ft}$ <p><math>\phi M_{n,2}</math></p> $\phi M_{n,2} = 0.85 f'_c S_m$	

$$\phi M_{n,z} = \phi S_x F_y$$

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

$$\phi M_{n,z} = 2545.9 \text{ kipft}$$

Therefore,

$\phi M_n$  - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$

$$\phi M_n = 273.42 \text{ kipft}$$

**Considering x-direction:**

$M_{max} = 18.221 \text{ kipft}$  - Maximum moment in the x-direction,

*Ratio* - Capacity

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

$$\text{Ratio} = \frac{(18.221 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$\text{Ratio} = 0.066642$$

Status: **PASS**  
Ratio: **0.070**