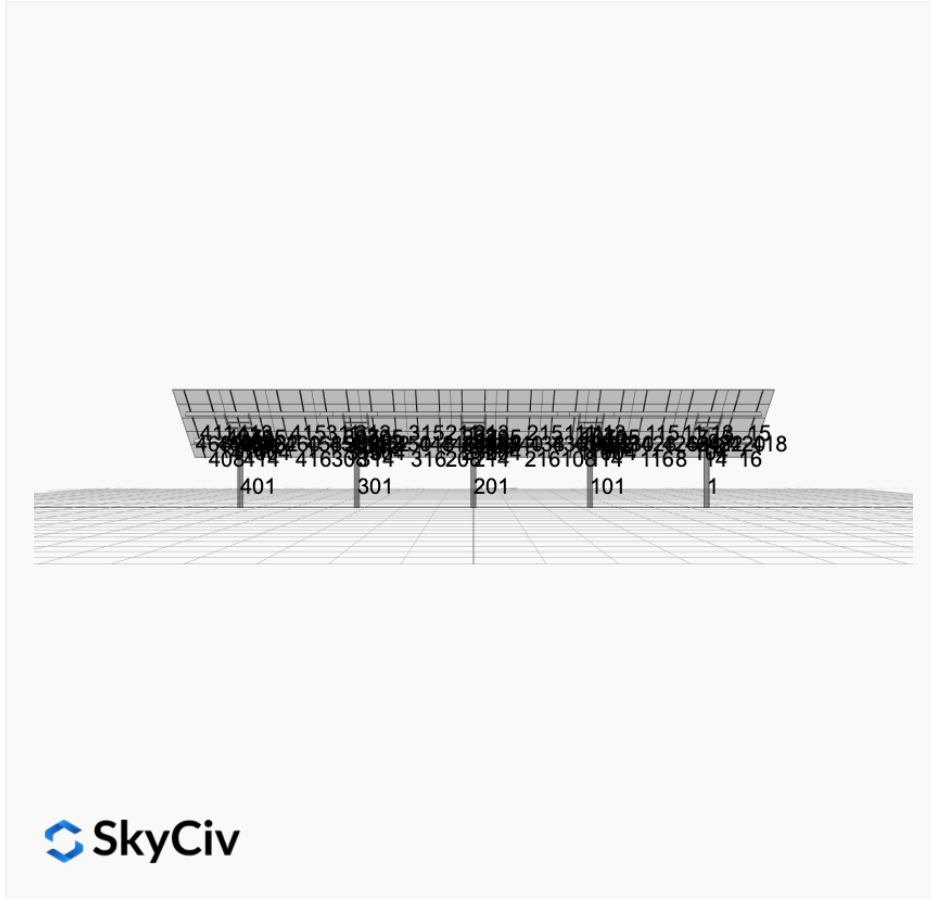


Project Details



Project Name: Bzn Trail II Aptos - V1Jb **Date:** Fri Apr 25 2025
Location: 31842 Frontage Rd, Bozeman, MT 59715, USA **Number of Modules:** 65
Unique ID: 5P-19.75-10TOP-XD-57-L-5Hx13W-0507 **Number of Poles:** 5
Dealer: _____ **Date Sold:** _____



Array Dimensions N/S	18.79 ft
Array Dimensions E/W	98.24 ft
Winter Tilt Angle	36
Front Edge Clearance	8 ft

MT Solar Bill of Materials (5P-19.75-10TOP-XD-57-L-5Hx13W-0507)

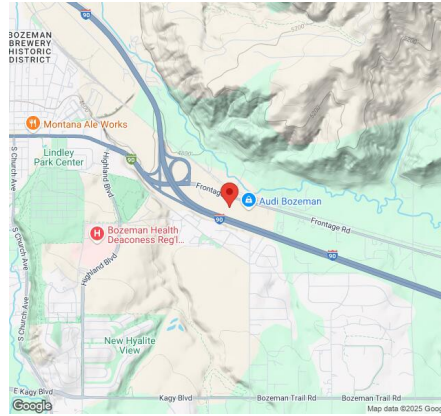
Part	Short Description	BOM Qty
MTS-PC-10	10IN Pole Cap Assembly	5
MTS-HF-XD	H-Frame Assembly-XD	5
MTS-XD-Wing-57	57IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	8
MTS-XD-Splice-57	57IN XD Splice	8
MTS-CLAMP-ANGLE-4PK	Angle Clamp	13

Rail Bill of Materials

Part	Qty
Rails (226in)	26
Rail Attachment	104

Part	Qty
Module Mid Clamp	104
Module End Clamp	52
Ground Lug	13

Site Details:



Site Address: 31842 Frontage Rd, Bozeman, MT 59715, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	89.68in
Number of Rows:	5
Number of Columns:	13
Total Number of Modules:	65
Winter Tilt Angle:	36
Front Edge Clearance:	8
Total Array Height at Tilt:	19.05 ft
Total Frame Length:	96.00 ft
Module Info/Notes:	DNA-144BF10-550W-DG
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	98.24 ft
Rail Length:	225.50 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	13.52 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 8.50 ft Pile 2: 8.50 ft Pile 3: 8.75 ft Pile 4: 8.50 ft Pile 5: 8.50 ft
Foundation Volume:	25.333 y ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	31842 Frontage Rd, Bozeman, MT 59715, USA
Wind Speed:	115 mph

Snow Load:

51 psf

Design Disclaimer

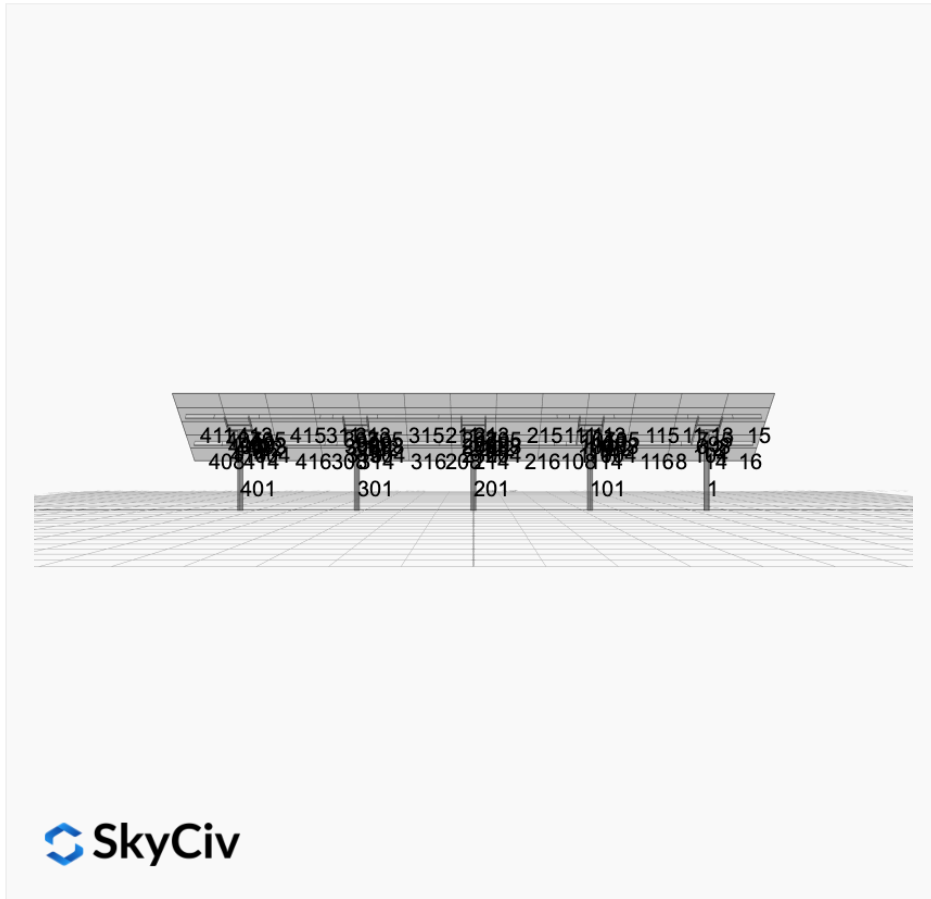
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

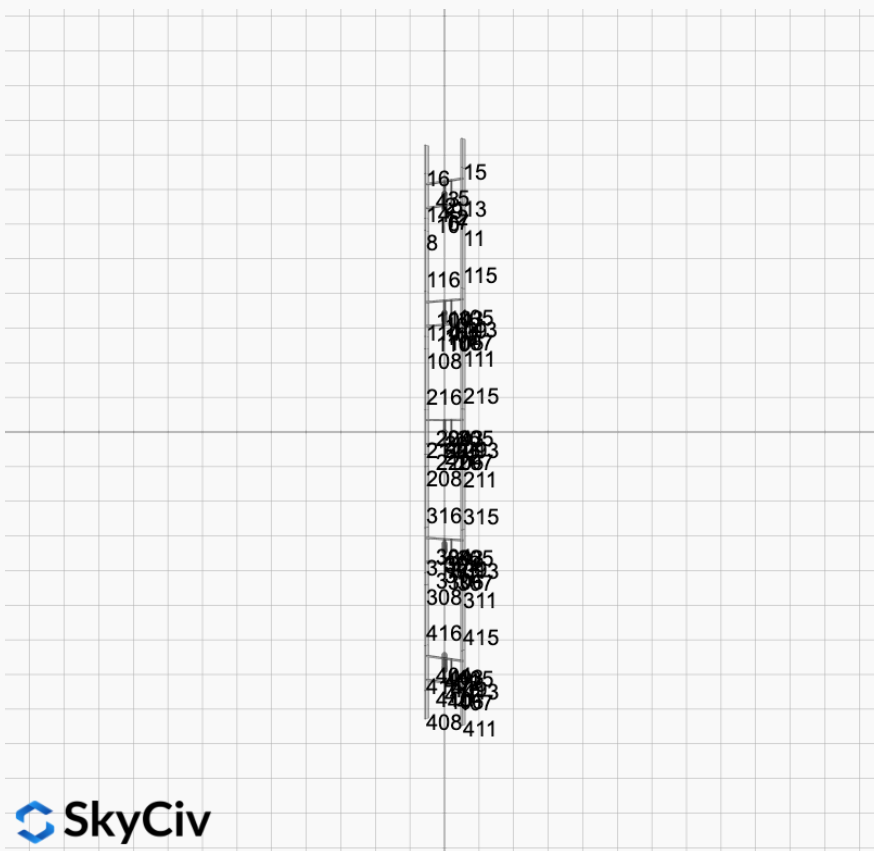
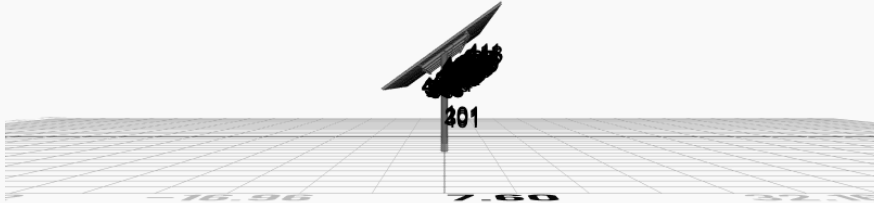
AutoDesigner Input

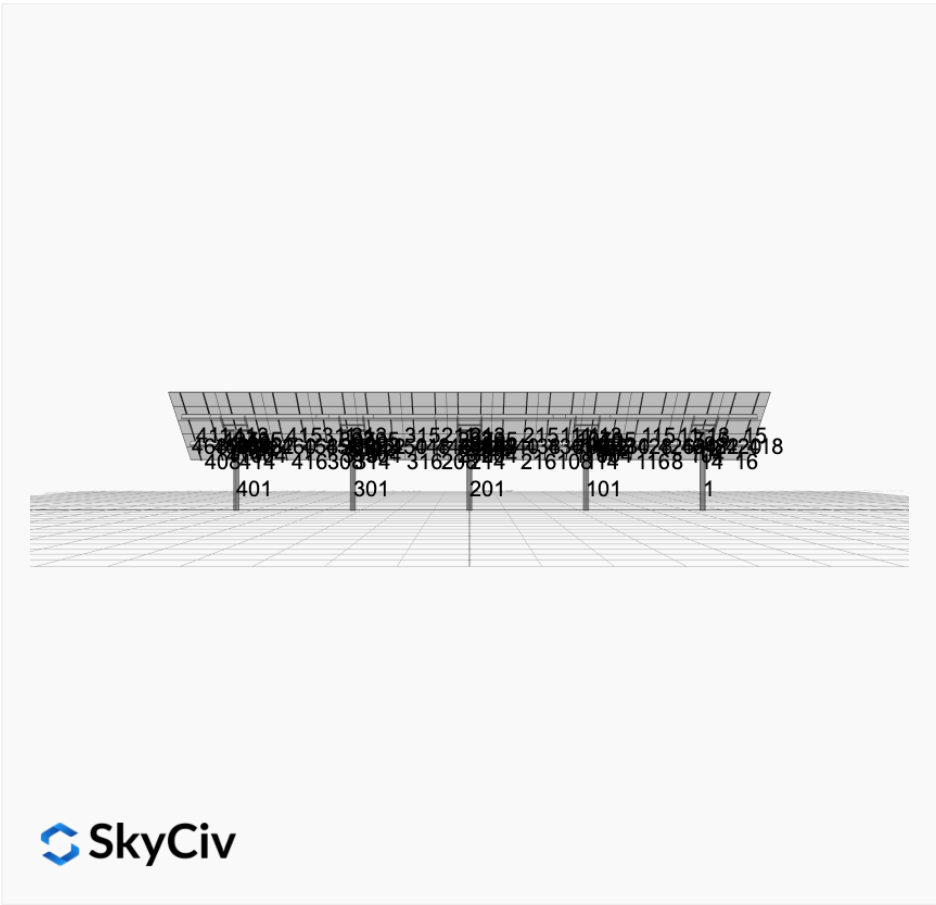
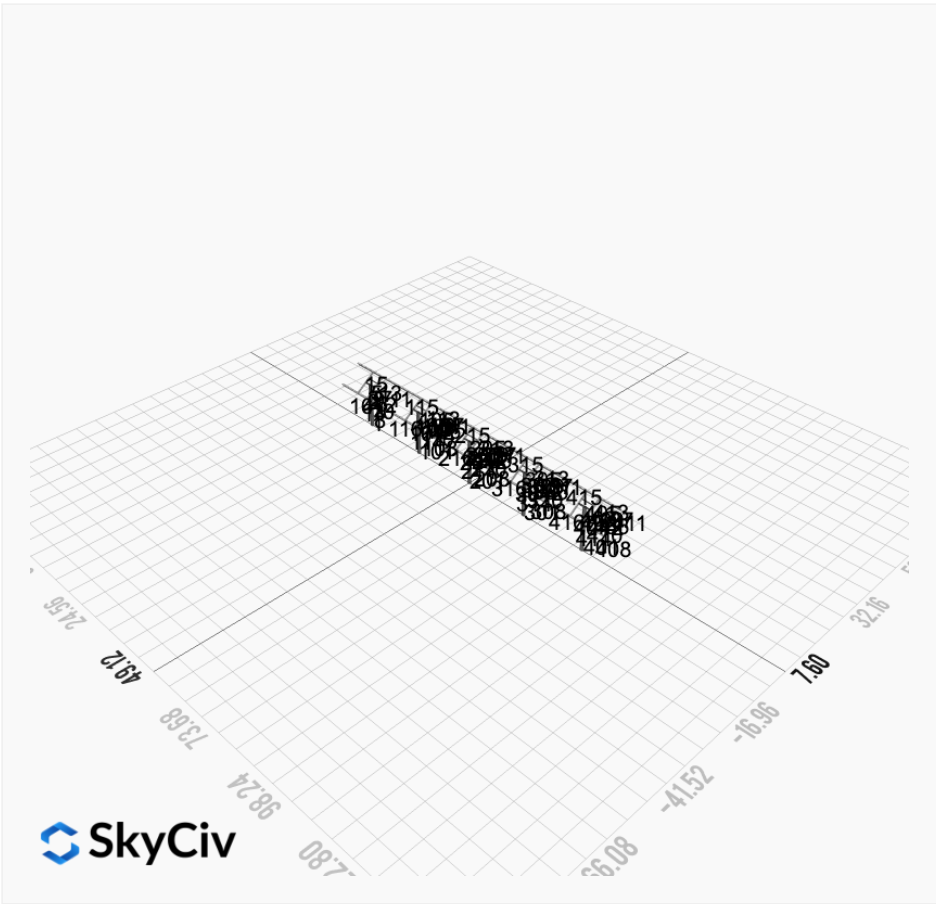
```
{"wind_speed_override":115,"snow_load_override":51,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Thomas Burney","designer_email":"thomas.burney@onsiteenergyinc.com","designer_phone":"","project_id":"Bzn Trail II Aptos - V1Jb","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_info":"DNA-144BF10-550W-DG","module_width":44.6,"module_length":89.68,"number_rows":5,"number_columns":13,"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":36,"ground_clearance":8,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Square","foundation_size":48,"check_rails":false}
```

Design Notes:

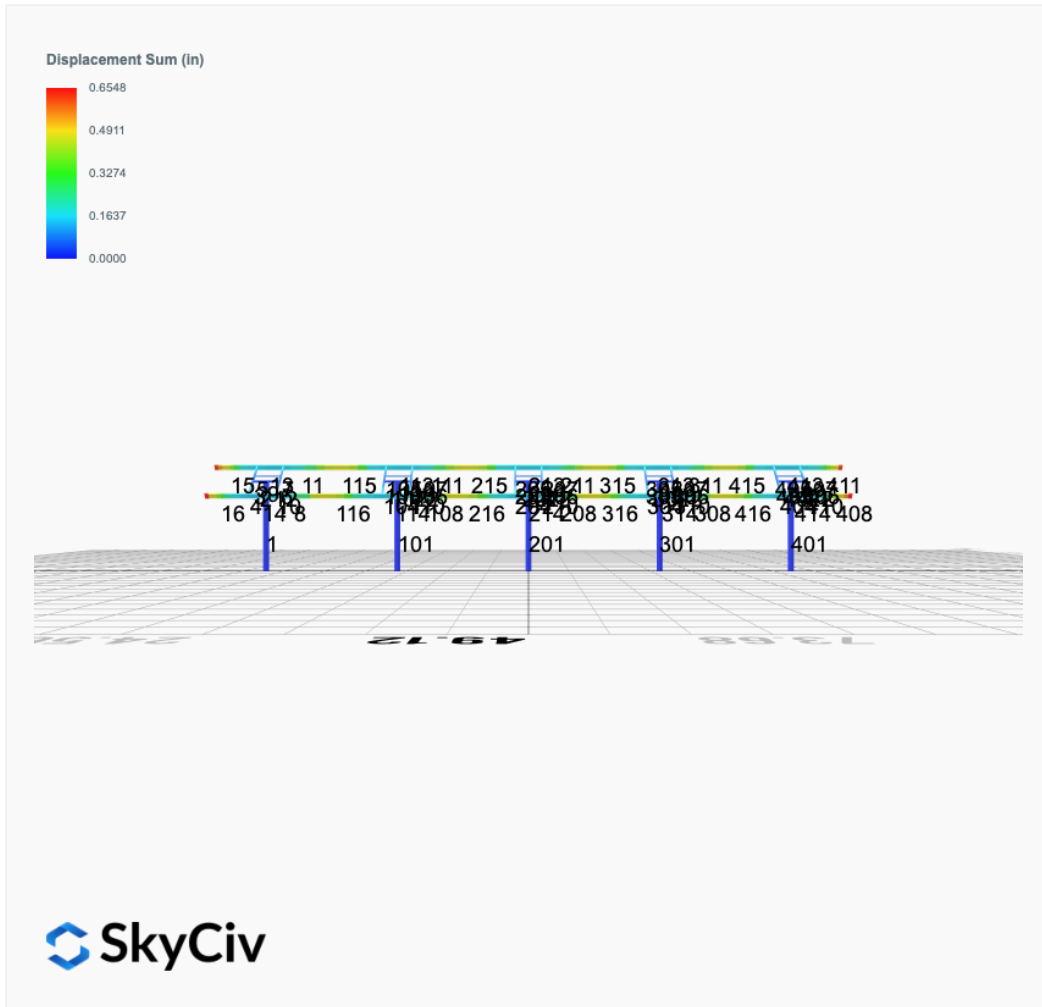
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame design checks are based on AISC 360 2016 (LRFD)



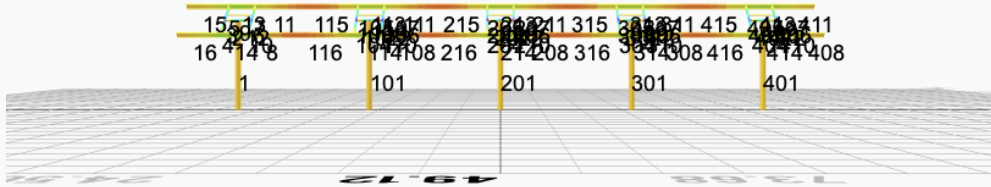
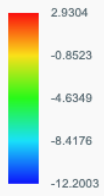




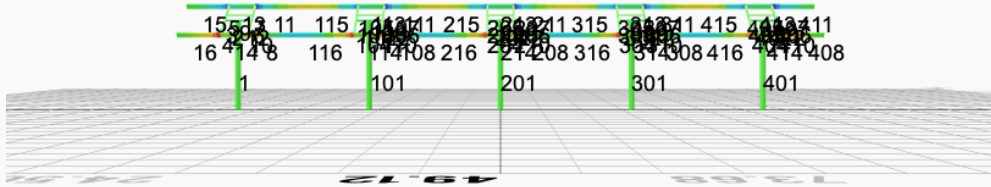
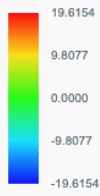
FEM Results (Envelope Worst Case for each member)



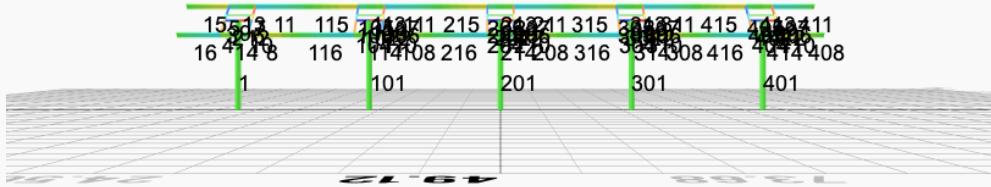
Top Bending Stress Z (ksi)



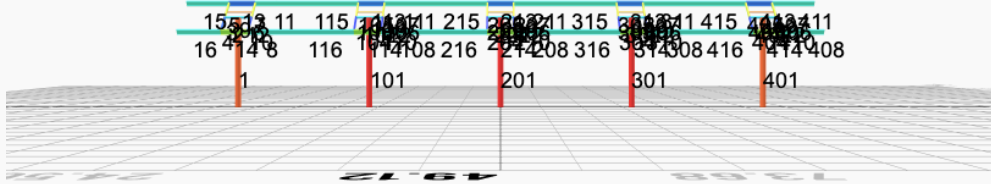
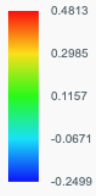
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0053	2.8321	-0.0011	-0.0006	0.0476	0.0972
ULS: 2. D + L	-0.0053	2.8321	-0.0011	-0.0006	0.0476	0.0972
ULS: 3. D + (S or Lr or R)	-0.0193	8.1799	-0.0037	-0.0002	0.1725	0.3056
ULS: 3. D + (S or Lr or R)	-0.0053	2.8321	-0.0011	-0.0006	0.0476	0.0972
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0158	6.8429	-0.0030	-0.0003	0.1413	0.2535
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0053	2.8321	-0.0011	-0.0006	0.0476	0.0972
ULS: 5b. D + 0.7E	-0.0053	2.8321	-0.0011	-0.0006	0.0476	0.0972
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0158	6.8429	-0.0030	-0.0003	0.1413	0.2535
ULS: 8. 0.6D + 0.7E	-0.0032	1.6992	-0.0007	-0.0004	0.0285	0.0583
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.7122	9.2911	0.0012	0.0063	0.0202	65.7072
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.7122	9.2911	0.0012	0.0063	0.0202	65.7072
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.9519	-2.5997	-0.0015	-0.0009	0.0630	-52.5657
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2986	-1.6978	-0.0066	-0.0194	0.0863	-56.6111
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5460	11.6872	-0.0013	0.0049	0.1208	49.4610
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5460	11.6872	-0.0013	0.0049	0.1208	49.4610
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9522	2.7691	-0.0033	-0.0005	0.1528	-39.2437
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4622	3.4455	-0.0071	-0.0144	0.1703	-42.2777
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5355	7.6763	0.0006	0.0046	0.0271	49.3047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5355	7.6763	0.0006	0.0046	0.0271	49.3047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9626	-1.2418	-0.0014	-0.0008	0.0591	-39.4000
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4726	-0.5654	-0.0052	-0.0147	0.0766	-42.4340
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.7101	8.1582	0.0016	0.0065	0.0012	65.6683
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.7101	8.1582	0.0016	0.0065	0.0012	65.6683
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.9541	-3.7325	-0.0011	-0.0006	0.0439	-52.6046
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.3008	-2.8307	-0.0061	-0.0191	0.0673	-56.6500

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.3378
Shear X	-7.8592
Shear Z	-0.0122
Moment X	-0.0333
Moment Y (Twist)	0.2939
Moment Z	111.0039

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	11.6872
Shear X	-4.7122
Shear Z	-0.0071
Moment X	-0.0194
Moment Y (Twist)	0.1725
Moment Z	65.7072

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	0.0059	2.9648	0.0018	0.0073	-0.0095	-0.0429
ULS: 2. D + L	0.0059	2.9648	0.0018	0.0073	-0.0095	-0.0429
ULS: 3. D + (S or Lr or R)	0.0212	8.6659	0.0066	0.0265	-0.0346	-0.2006
ULS: 3. D + (S or Lr or R)	0.0059	2.9648	0.0018	0.0073	-0.0095	-0.0429
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0174	7.2406	0.0054	0.0217	-0.0283	-0.1612

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0059	2.9648	0.0018	0.0073	-0.0095	-0.0429
ULS: 5b. D + 0.7E	0.0059	2.9648	0.0018	0.0073	-0.0095	-0.0429
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0174	7.2406	0.0054	0.0217	-0.0283	-0.1612
ULS: 8. 0.6D + 0.7E	0.0035	1.7789	0.0011	0.0044	-0.0057	-0.0257
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.9330	9.7756	0.0261	0.0975	-0.1298	68.7718
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.9330	9.7756	0.0261	0.0975	-0.1298	68.7718
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.1613	-2.7648	-0.0173	-0.0635	0.0848	-55.2126
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.4640	-1.8066	-0.0182	-0.0666	0.0917	-59.3521
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6867	12.3487	0.0236	0.0894	-0.1185	51.4498
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6867	12.3487	0.0236	0.0894	-0.1185	51.4498
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1339	2.9434	-0.0089	-0.0313	0.0424	-41.5385
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.6110	3.6621	-0.0096	-0.0337	0.0476	-44.6431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6982	8.0729	0.0200	0.0749	-0.0997	51.5681
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6982	8.0729	0.0200	0.0749	-0.0997	51.5681
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1224	-1.3324	-0.0125	-0.0458	0.0612	-41.4202
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.5995	-0.6137	-0.0132	-0.0481	0.0664	-44.5248
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.9353	8.5897	0.0254	0.0946	-0.1260	68.7889
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.9353	8.5897	0.0254	0.0946	-0.1260	68.7889
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.1589	-3.9507	-0.0180	-0.0664	0.0886	-55.1954
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.4617	-2.9925	-0.0189	-0.0695	0.0955	-59.3350

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.3548
Shear X	-8.2314
Shear Z	0.0458
Moment X	0.1715
Moment Y (Twist)	0.2282
Moment Z	116.1071

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	12.3487
Shear X	-4.9353
Shear Z	0.0261
Moment X	0.0975
Moment Y (Twist)	0.1298
Moment Z	68.7889

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	-0.0011	2.9762	-0.0000	0.0000	0.0000	0.0364
ULS: 2. D + L	-0.0011	2.9762	-0.0000	0.0000	0.0000	0.0364
ULS: 3. D + (S or Lr or R)	-0.0039	8.7071	0.0000	0.0000	0.0000	0.0877
ULS: 3. D + (S or Lr or R)	-0.0011	2.9762	-0.0000	0.0000	0.0000	0.0364
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0032	7.2744	0.0000	0.0000	0.0000	0.0749
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0011	2.9762	-0.0000	0.0000	0.0000	0.0364
ULS: 5b. D + 0.7E	-0.0011	2.9762	-0.0000	0.0000	0.0000	0.0364
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0032	7.2744	0.0000	0.0000	0.0000	0.0749
ULS: 8. 0.6D + 0.7E	-0.0006	1.7857	-0.0000	0.0000	0.0000	0.0218
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.0128	9.8871	-0.0000	0.0000	0.0000	69.9085
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.0128	9.8871	-0.0000	0.0000	0.0000	69.9085
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.2154	-2.8370	-0.0000	0.0000	0.0000	-55.9450
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.5097	-1.8678	-0.0000	0.0000	0.0000	-60.1653

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	-3.7620	12.4575	0.0000	0.0000	0.0000	52.4789
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.7620	12.4575	0.0000	0.0000	0.0000	52.4789
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1592	2.9145	0.0000	0.0000	0.0000	-41.9112
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.6299	3.6414	0.0000	0.0000	0.0000	-45.0764
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.7599	8.1594	-0.0000	0.0000	0.0000	52.4405
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.7599	8.1594	-0.0000	0.0000	0.0000	52.4405
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1613	-1.3837	-0.0000	0.0000	0.0000	-41.9496
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.6320	-0.6568	-0.0000	0.0000	0.0000	-45.1149
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.0124	8.6966	0.0000	0.0000	0.0000	69.8940
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.0124	8.6966	0.0000	0.0000	0.0000	69.8940
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.2159	-4.0275	-0.0000	0.0000	0.0000	-55.9595
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.5101	-3.0582	-0.0000	0.0000	0.0000	-60.1799

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.4999
Shear X	-8.3552
Shear Z	-0.0000
Moment X	0.0003
Moment Y (Twist)	0.0002
Moment Z	118.1131

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	12.4575
Shear X	-5.0128
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	69.9085

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0059	2.9648	-0.0018	-0.0072	0.0095	-0.0429
ULS: 2. D + L	0.0059	2.9648	-0.0018	-0.0072	0.0095	-0.0429
ULS: 3. D + (S or Lr or R)	0.0212	8.6659	-0.0066	-0.0265	0.0346	-0.2006
ULS: 3. D + (S or Lr or R)	0.0059	2.9648	-0.0018	-0.0072	0.0095	-0.0429
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0174	7.2406	-0.0054	-0.0217	0.0283	-0.1612
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0059	2.9648	-0.0018	-0.0072	0.0095	-0.0429
ULS: 5b. D + 0.7E	0.0059	2.9648	-0.0018	-0.0072	0.0095	-0.0429
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0174	7.2406	-0.0054	-0.0217	0.0283	-0.1612
ULS: 8. 0.6D + 0.7E	0.0035	1.7789	-0.0011	-0.0043	0.0057	-0.0257
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.9330	9.7756	-0.0261	-0.0975	0.1298	68.7718
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.9330	9.7756	-0.0261	-0.0975	0.1298	68.7718
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.1613	-2.7648	0.0173	0.0635	-0.0848	-55.2126
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.4640	-1.8066	0.0182	0.0666	-0.0917	-59.3521
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6867	12.3487	-0.0236	-0.0894	0.1185	51.4498
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6867	12.3487	-0.0236	-0.0894	0.1185	51.4498
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1339	2.9434	0.0089	0.0313	-0.0424	-41.5385
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.6110	3.6621	0.0096	0.0337	-0.0476	-44.6431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6982	8.0729	-0.0200	-0.0749	0.0997	51.5681
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6982	8.0729	-0.0200	-0.0749	0.0997	51.5681
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.1224	-1.3324	0.0125	0.0458	-0.0612	-41.4202
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.5995	-0.6137	0.0132	0.0482	-0.0664	-44.5248

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.9353	8.5897	-0.0254	-0.0946	0.1260	68.7889
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.9353	8.5897	-0.0254	-0.0946	0.1260	68.7889
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.1589	-3.9507	0.0180	0.0664	-0.0886	-55.1954
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.4617	-2.9925	0.0189	0.0695	-0.0955	-59.3350

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.3548
Shear X	-8.2314
Shear Z	-0.0458
Moment X	-0.1713
Moment Y (Twist)	0.2284
Moment Z	116.1072

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	12.3487
Shear X	-4.9353
Shear Z	-0.0261
Moment X	-0.0975
Moment Y (Twist)	0.1298
Moment Z	68.7889

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0053	2.8321	0.0011	0.0006	-0.0475	0.0972
ULS: 2. D + L	-0.0053	2.8321	0.0011	0.0006	-0.0475	0.0972
ULS: 3. D + (S or Lr or R)	-0.0193	8.1799	0.0037	0.0002	-0.1725	0.3056
ULS: 3. D + (S or Lr or R)	-0.0053	2.8321	0.0011	0.0006	-0.0475	0.0972
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0158	6.8429	0.0030	0.0003	-0.1412	0.2535
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0053	2.8321	0.0011	0.0006	-0.0475	0.0972
ULS: 5b. D + 0.7E	-0.0053	2.8321	0.0011	0.0006	-0.0475	0.0972
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0158	6.8429	0.0030	0.0003	-0.1412	0.2535
ULS: 8. 0.6D + 0.7E	-0.0032	1.6992	0.0007	0.0004	-0.0285	0.0583
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.7122	9.2911	-0.0012	-0.0063	-0.0202	65.7072
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.7122	9.2911	-0.0012	-0.0063	-0.0202	65.7072
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.9519	-2.5997	0.0015	0.0009	-0.0630	-52.5657
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2986	-1.6978	0.0066	0.0194	-0.0863	-56.6111
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5460	11.6872	0.0013	-0.0049	-0.1207	49.4610
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5460	11.6872	0.0013	-0.0049	-0.1207	49.4610
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9522	2.7691	0.0033	0.0005	-0.1528	-39.2437
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4622	3.4455	0.0071	0.0144	-0.1703	-42.2777
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.5355	7.6763	-0.0006	-0.0046	-0.0270	49.3047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.5355	7.6763	-0.0006	-0.0046	-0.0270	49.3047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9626	-1.2418	0.0014	0.0008	-0.0591	-39.4000
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4726	-0.5654	0.0052	0.0147	-0.0766	-42.4340
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.7101	8.1582	-0.0016	-0.0065	-0.0012	65.6683
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.7101	8.1582	-0.0016	-0.0065	-0.0012	65.6683
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.9541	-3.7325	0.0011	0.0006	-0.0439	-52.6045
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.3008	-2.8307	0.0061	0.0191	-0.0673	-56.6500

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.

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	17.3378
Shear X	-7.8593
Shear Z	0.0122
Moment X	0.0338
Moment Y (Twist)	0.2936
Moment Z	111.0048

Result	Value (kip, kip-ft)
Axial	11.6872
Shear X	-4.7122
Shear Z	0.0071
Moment X	0.0194
Moment Y (Twist)	0.1725
Moment Z	65.7072

Project Details

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

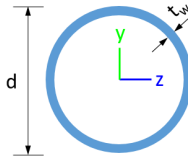


Design Input Information

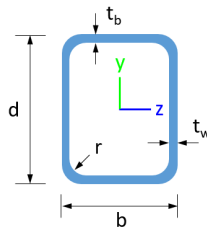
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

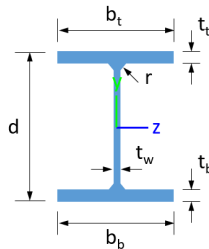
Section Dimensions



ID	Name	d (in)	t_w (in)				
3	2in Pipe Sch 120	2.38	0.25				
6	4in Pipe Sch 120	4.50	0.44				
11	10in Pipe Sch 40	10.75	0.36				



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



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

Section Properties

ID	Name	A (in ²)	J (in ⁴)	I_{yp} (in ⁴)	I_{zp} (in ⁴)	I_w (in ⁶)	S_{yp} (in ³)	S_{zp} (in ³)
----	------	----------------------	----------------------	-----------------------------	-----------------------------	--------------------------	-----------------------------	-----------------------------

104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.66	6.46	56.26	44.91
114	159.30	97.43	31.70	6.46	56.26	44.91
115	159.30	75.13	21.79	6.46	56.26	44.91
116	159.30	75.13	21.78	6.46	56.26	44.91
201	535.87	285.67	147.68	147.68	160.76	160.76
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.40	6.46	56.26	44.91
214	159.30	97.43	31.33	6.46	56.26	44.91
215	159.30	75.13	22.10	6.46	56.26	44.91
216	159.30	75.13	21.96	6.46	56.26	44.91
301	535.87	285.67	147.68	147.68	160.76	160.76
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	140.46	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	140.46	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	31.67	6.46	56.26	44.91
314	159.30	97.43	31.70	6.46	56.26	44.91
315	159.30	75.13	21.96	6.46	56.26	44.91
316	159.30	75.13	21.71	6.46	56.26	44.91
401	535.87	285.67	147.68	147.68	160.76	160.76
402	251.01	248.88	27.16	27.16	75.30	75.30
403	151.65	150.70	20.17	14.14	54.12	28.95
404	151.65	145.15	20.17	14.14	54.12	28.95
405	151.65	149.10	20.17	14.14	54.12	28.95
406	151.65	150.70	20.17	14.14	54.12	28.95
407	151.65	149.10	20.17	14.14	54.12	28.95

407	151.05	149.10	20.17	14.14	54.12	28.95
408	159.30	34.37	46.90	6.46	56.26	44.91
409	75.10	66.32	4.25	4.25	22.53	22.53
410	151.65	145.15	20.17	14.14	54.12	28.95
411	159.30	34.37	46.90	6.46	56.26	44.91
412	251.01	248.88	27.16	27.16	75.30	75.30
413	159.30	97.43	33.15	6.46	56.26	44.91
414	159.30	97.43	32.38	6.46	56.26	44.91
415	159.30	75.13	21.82	6.46	56.26	44.91
416	159.30	75.13	22.24	6.46	56.26	44.91

Design Ratio

Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.061	0.752	0.001	0.049	0.000	0.781	#13	0.464	Not Required	Pass
2	0.004	0.504	0.283	0.110	0.053	0.788	#13	0.036	Not Required	Pass
3	0.011	0.831	0.057	0.083	0.005	0.863	#13	0.046	Not Required	Pass
4	0.010	0.806	0.198	0.080	0.042	0.865	#13	0.082	Not Required	Pass
5	0.010	0.516	0.205	0.082	0.053	0.538	#13	0.076	Not Required	Pass
6	0.011	0.835	0.066	0.083	0.006	0.869	#13	0.046	Not Required	Pass
7	0.011	0.518	0.208	0.083	0.055	0.545	#13	0.076	Not Required	Pass
8	0.000	0.054	0.213	0.052	0.024	0.251	#21	0.102	Not Required	Pass
9	0.021	0.071	0.059	0.001	0.000	0.130	#13	0.206	Not Required	Pass
10	0.011	0.802	0.203	0.080	0.044	0.865	#13	0.082	Not Required	Pass
11	0.000	0.057	0.216	0.054	0.024	0.257	#21	0.102	Not Required	Pass
12	0.004	0.505	0.280	0.111	0.052	0.786	#13	0.036	Not Required	Pass
13	0.010	0.327	0.572	0.068	0.031	0.840	#21	0.306	Not Required	Pass
14	0.012	0.321	0.572	0.066	0.031	0.836	#21	0.204	Not Required	Pass
15	0.000	0.115	0.305	0.040	0.018	0.407	#21	Not Required	Not Required	Pass
16	0.000	0.112	0.305	0.039	0.018	0.406	#21	Not Required	Not Required	Pass
101	0.064	0.786	0.003	0.051	0.000	0.818	#13	0.464	Not Required	Pass
102	0.004	0.521	0.288	0.117	0.054	0.810	#13	0.036	Not Required	Pass
103	0.012	0.867	0.071	0.086	0.010	0.904	#13	0.046	Not Required	Pass
104	0.012	0.843	0.196	0.084	0.043	0.911	#13	0.082	Not Required	Pass
105	0.012	0.538	0.201	0.086	0.051	0.562	#13	0.076	Not Required	Pass
106	0.012	0.886	0.072	0.088	0.011	0.923	#13	0.046	Not Required	Pass
107	0.012	0.550	0.200	0.088	0.051	0.575	#13	0.076	Not Required	Pass
108	0.001	0.068	0.208	0.050	0.024	0.237	#21	0.102	Not Required	Pass
109	0.018	0.072	0.057	0.001	0.000	0.134	#13	0.206	Not Required	Pass
110	0.012	0.857	0.194	0.085	0.042	0.916	#13	0.082	Not Required	Pass
111	0.001	0.071	0.212	0.052	0.024	0.242	#21	0.102	Not Required	Pass
112	0.004	0.537	0.296	0.118	0.055	0.834	#13	0.036	Not Required	Pass
113	0.009	0.261	0.546	0.067	0.031	0.755	#21	0.306	Not Required	Pass
114	0.012	0.263	0.544	0.065	0.031	0.750	#21	0.306	Not Required	Pass
115	0.001	0.309	0.297	0.050	0.024	0.569	#21	0.507	Not Required	Pass
116	0.000	0.299	0.299	0.049	0.024	0.567	#21	0.507	Not Required	Pass
201	0.065	0.800	0.000	0.052	0.000	0.831	#13	0.464	Not Required	Pass
202	0.004	0.536	0.297	0.118	0.055	0.833	#13	0.036	Not Required	Pass
203	0.012	0.888	0.072	0.088	0.010	0.925	#13	0.046	Not Required	Pass
204	0.012	0.861	0.194	0.086	0.042	0.925	#13	0.082	Not Required	Pass
205	0.012	0.551	0.200	0.088	0.052	0.576	#13	0.076	Not Required	Pass

206	0.012	0.888	0.072	0.088	0.010	0.925	#13	0.046	Not Required	Pass
207	0.012	0.551	0.200	0.088	0.052	0.576	#13	0.076	Not Required	Pass
208	0.001	0.064	0.210	0.051	0.024	0.245	#21	0.102	Not Required	Pass
209	0.018	0.070	0.057	0.001	0.000	0.131	#13	0.206	Not Required	Pass
210	0.012	0.861	0.194	0.086	0.042	0.925	#13	0.082	Not Required	Pass
211	0.001	0.070	0.213	0.052	0.024	0.247	#21	0.102	Not Required	Pass
212	0.004	0.536	0.297	0.118	0.055	0.833	#13	0.036	Not Required	Pass
213	0.009	0.269	0.545	0.067	0.031	0.760	#21	0.306	Not Required	Pass
214	0.012	0.273	0.542	0.065	0.031	0.757	#21	0.306	Not Required	Pass
215	0.001	0.328	0.297	0.052	0.024	0.584	#21	0.507	Not Required	Pass
216	0.001	0.312	0.299	0.051	0.024	0.579	#21	0.507	Not Required	Pass
301	0.064	0.786	0.003	0.051	0.000	0.818	#13	0.464	Not Required	Pass
302	0.004	0.537	0.296	0.118	0.055	0.834	#13	0.036	Not Required	Pass
303	0.012	0.886	0.072	0.088	0.011	0.923	#13	0.046	Not Required	Pass
304	0.012	0.857	0.194	0.085	0.042	0.916	#13	0.082	Not Required	Pass
305	0.012	0.550	0.200	0.088	0.051	0.575	#13	0.076	Not Required	Pass
306	0.012	0.867	0.071	0.086	0.010	0.904	#13	0.046	Not Required	Pass
307	0.012	0.538	0.201	0.086	0.051	0.562	#13	0.076	Not Required	Pass
308	0.000	0.065	0.211	0.049	0.024	0.244	#21	0.102	Not Required	Pass
309	0.018	0.072	0.057	0.001	0.000	0.134	#13	0.206	Not Required	Pass
310	0.012	0.843	0.196	0.084	0.043	0.911	#13	0.082	Not Required	Pass
311	0.000	0.069	0.214	0.050	0.024	0.247	#21	0.102	Not Required	Pass
312	0.004	0.521	0.288	0.117	0.054	0.810	#13	0.036	Not Required	Pass
313	0.009	0.261	0.546	0.067	0.031	0.755	#21	0.306	Not Required	Pass
314	0.012	0.263	0.544	0.065	0.031	0.750	#21	0.306	Not Required	Pass
315	0.001	0.328	0.297	0.052	0.024	0.584	#21	0.507	Not Required	Pass
316	0.001	0.314	0.299	0.050	0.024	0.580	#21	0.507	Not Required	Pass
401	0.061	0.752	0.001	0.049	0.000	0.781	#13	0.464	Not Required	Pass
402	0.004	0.505	0.280	0.111	0.052	0.786	#13	0.036	Not Required	Pass
403	0.011	0.835	0.066	0.083	0.006	0.869	#13	0.046	Not Required	Pass
404	0.011	0.802	0.203	0.080	0.044	0.865	#13	0.082	Not Required	Pass
405	0.011	0.518	0.208	0.083	0.055	0.545	#13	0.076	Not Required	Pass
406	0.011	0.831	0.057	0.083	0.005	0.863	#13	0.046	Not Required	Pass
407	0.010	0.516	0.205	0.082	0.053	0.538	#13	0.076	Not Required	Pass
408	0.000	0.112	0.305	0.039	0.018	0.406	#21	Not Required	Not Required	Pass
409	0.021	0.071	0.059	0.001	0.000	0.130	#13	0.206	Not Required	Pass
410	0.010	0.806	0.198	0.080	0.042	0.865	#13	0.082	Not Required	Pass
411	0.000	0.115	0.305	0.040	0.018	0.407	#21	Not Required	Not Required	Pass
412	0.004	0.504	0.283	0.110	0.053	0.788	#13	0.036	Not Required	Pass
413	0.010	0.327	0.572	0.068	0.031	0.840	#21	0.204	Not Required	Pass
414	0.012	0.321	0.572	0.066	0.031	0.836	#21	0.306	Not Required	Pass
415	0.001	0.301	0.297	0.054	0.024	0.563	#21	0.507	Not Required	Pass
416	0.000	0.294	0.299	0.052	0.024	0.562	#21	0.507	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_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
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS
------------	--------------	---------

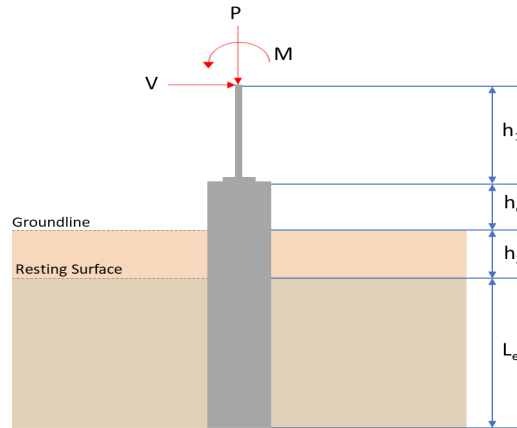
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.687	17.338
V_x (kip)	-4.712	-7.859
V_z (kip)	-0.007	-0.012
M_x (kipft)	-0.019	-0.033
M_z (kipft)	65.707	111.004

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.712 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.75032 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(65.707 \text{ kipft}) + ((-4.712 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.463 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.8495 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.007 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0011146 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.019 \text{ kipft}) + ((-0.007 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0030255 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.58795 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.8495 \text{ ft}), (0.58795 \text{ ft})]$$

$$L_{e,req} = 7.85 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.85 \text{ ft})}{(8.5 \text{ ft})}$$

$$\text{Ratio} = 0.92353$$

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

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

$$q = \frac{(11.687 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.73044 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.73044 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.36522$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.75032 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 10.463 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.463 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (10.463 \text{ kipft/ft})) + (4 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8713 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.463 \text{ kipft/ft})) + (3 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (10.463 \text{ kipft/ft})) + (2 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.28754 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (10.463 \text{ kipft/ft})) + ((-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.2081 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8713 \text{ ft})}{2}$$

$$p_a = 0.44035 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.28754 \text{ kip/ft}^2)}{(0.44035 \text{ kip/ft}^2)}$$

$$Ratio = 0.65297$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.2081 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.94757$$

Status: **PASS**
Ratio: **0.650**

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

Considering z-direction:

$H_o = -0.0011146 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0030255 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0030255 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.0030255 \text{ kipft/ft})) + (4 \times (-0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1456 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.0030255 \text{ kipft/ft})) + (3 \times (-0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 [(3 \times (0.0030255 \text{ kipft/ft})) + (2 \times (-0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = -0.0002801 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0030255 \text{ kipft/ft})) + ((-0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = -0.00028431 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.1456 \text{ ft})}{2}$$

$$p_a = 0.46092 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.0002801 \text{ kip/ft}^2)}{(0.46092 \text{ kip/ft}^2)}$$

$$Ratio = -0.00060771$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

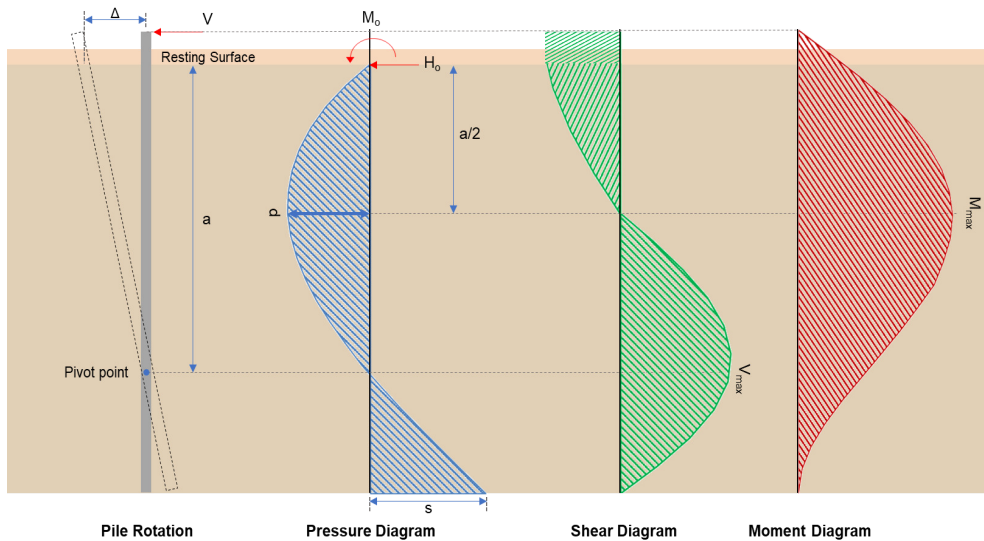
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(-0.00028431 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = -0.00022299$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.859 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.2514 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(111 \text{ kipft}) + ((-7.859 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 17.676 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(17.676 \text{ kipft/ft})}{(-1.2514 \text{ kip/ft})}$$

$$E = 14.124 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (17.676 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-1.2514 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times 17.676) + (4 \times (-1.2514) \times 8.5)}$$

$$a = \frac{(6 \times (17.676 \text{ kipft/ft})) + (4 \times (-1.2514 \text{ kip/ft}) \times (8.5 \text{ ft}))}{(6 \times (17.676 \text{ kipft/ft})) + (4 \times (-1.2514 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8695 \text{ ft}$$

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

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

$$V_{max} = ((-1.2514 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.124 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8695 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (14.124 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8695 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 18.02 \text{ kip}$$

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

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

$$M_{max} = ((-1.2514 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(14.124 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8695 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.124 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8695 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (14.124 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8695 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 72.724 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.012 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0019108 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.033 \text{ kipft}) + ((-0.012 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0052548 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0052548 \text{ kipft/ft})}{(-0.0019108 \text{ kip/ft})}$$

$$E = 2.75 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0052548 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.0019108 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.0052548 \text{ kipft/ft})) + (4 \times (-0.0019108 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1436 \text{ ft}$$

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

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

$$V_{max} = ((-0.0019108 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.75 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1436 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.75 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1436 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0095025 \text{ kip}$$

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

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

$$M_{max} = ((-0.0019108 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(2.75 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1436 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.75 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1436 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.75 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1436 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.034622 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(17.338 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.02 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.02 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(17.338 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0064811$</p>	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.338 \text{ kip} \rightarrow 17338 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(17338 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.8 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (120.8 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.8 \text{ kip}$$

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

$$V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = \text{MIN} [V_{s,a}, V_{s,b}]$$

$$V_s = \text{MIN} [(737.28 \text{ kip}), (50.894 \text{ kip})]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.8 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.6 \text{ kip}$$

Considering x-direction:

V_{max} = 18.02 kip - Maximum shear force in the x-direction,

Ratio - Capacity

$$\text{Ratio} = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(18.02 \text{ kip})}{(111.6 \text{ kip})}$$

$$Ratio = 0.16147$$

Status: **PASS**
Ratio: **0.160**

Considering z-direction:

$V_{max} = 0.0095025 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.0095025 \text{ kip})}{(111.6 \text{ kip})}$$

$$Ratio = 0.000085149$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 72.724 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(72.724 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.29136$$

Status: **PASS**
Ratio: **0.290**

Considering z-direction:

$M_{max} = 0.034622 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.034622 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00013871$$

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

REFERENCES	CALCULATIONS	RESULTS
------------	--------------	---------

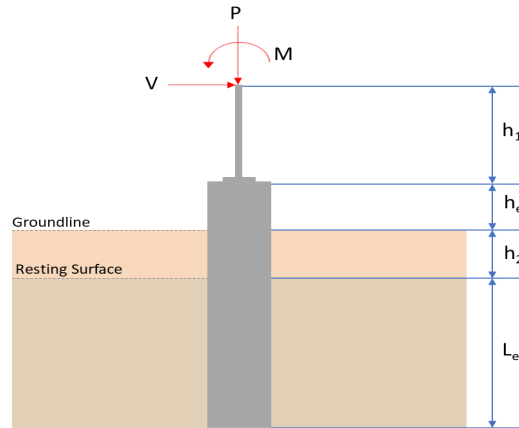
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.349	18.355
V_x (kip)	-4.935	-8.231
V_z (kip)	0.026	0.046
M_x (kipft)	0.097	0.172
M_z (kipft)	68.789	116.107

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.935 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.78583 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(68.789 \text{ kipft}) + ((-4.935 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.954 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.9457 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.097 \text{ kipft}) + ((0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.015446 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.1502 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.9457 \text{ ft}), (1.1502 \text{ ft})]$$

$$L_{e,req} = 7.946 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.946 \text{ ft})}{(8.5 \text{ ft})}$$

$$\text{Ratio} = 0.93482$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(12.349 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.77181 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.77181 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.38591$$

Status: **PASS**
Ratio: **0.390**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.78583 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 10.954 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.954 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (10.954 \text{ kipft/ft})) + (4 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8714 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.954 \text{ kipft/ft})) + (3 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (10.954 \text{ kipft/ft})) + (2 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.3009 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (10.954 \text{ kipft/ft})) + ((-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.2646 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8714 \text{ ft})}{2}$$

$$p_a = 0.44035 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.3009 \text{ kip/ft}^2)}{(0.44035 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.68332$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.2646 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.99184$$

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

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = 0.0041401 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.015446 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015446 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.015446 \text{ kipft/ft})) + (4 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0938 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.015446 \text{ kipft/ft})) + (3 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (0.015446 \text{ kipft/ft})) + (2 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.002491 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.015446 \text{ kipft/ft})) + ((0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 0.0054878 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0938 \text{ ft})}{2}$$

$$p_a = 0.45703 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.002491 \text{ kip/ft}^2)}{(0.45703 \text{ kip/ft}^2)}$$

$$Ratio = 0.0054502$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

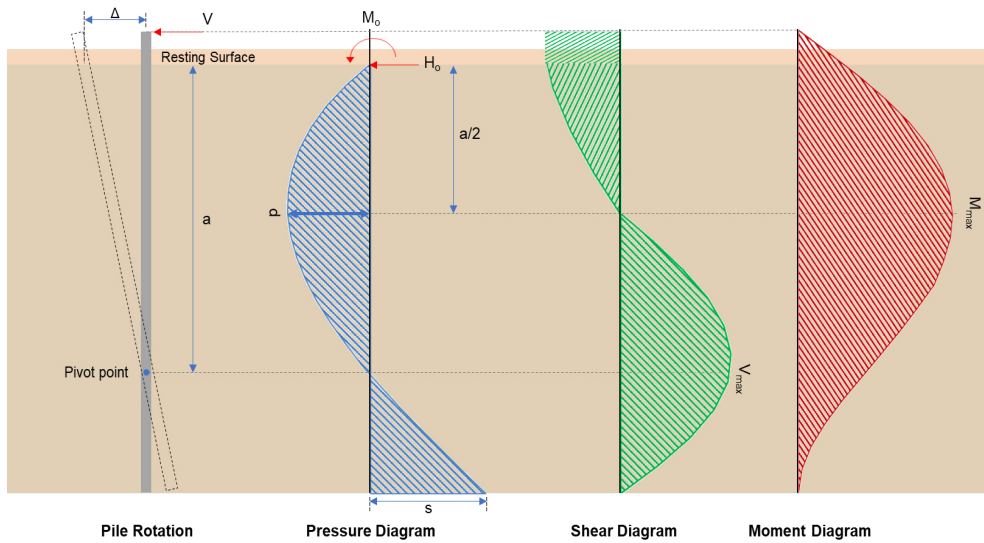
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0054878 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.0043042$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.231 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.3107 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(116.11 \text{ kipft}) + ((-8.231 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 18.488 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.488 \text{ kipft/ft})}{(-1.3107 \text{ kip/ft})}$$

$$E = 14.106 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.488 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (18.488 \text{ kipft/ft})) + (4 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = \frac{(6 \times (18.488 \text{ kipft/ft})) + (4 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft}))}{}$$

$$a = 5.8697 \text{ ft}$$

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

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

$$V_{max} = ((-1.3107 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8697 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8697 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 18.853 \text{ kip}$$

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

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

$$M_{max} = ((-1.3107 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(14.106 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8697 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8697 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8697 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 76.081 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.046 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0073248 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.172 \text{ kipft}) + ((0.046 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.027389 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.027389 \text{ kipft/ft})}{(0.0073248 \text{ kip/ft})}$$

$$E = 3.7391 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.027389 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (0.0073248 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.027389 \text{ kipft/ft})) + (4 \times (0.0073248 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0934 \text{ ft}$$

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

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

$$V_{max} = ((0.0073248 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7391 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.0934 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (3.7391 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.0934 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.042366 \text{ kip}$$

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

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

$$M_{max} = ((0.0073248 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.7391 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.0934 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (3.7391 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.0934 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.7391 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.0934 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.15788 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(18.355 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -83.986 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-83.986 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(18.355 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0068612$	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.355 \text{ kip} \rightarrow 18355 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(18355 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.93 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.93 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.93 \text{ kip}$$

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

$$V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = \text{MIN}[V_{s,a}, V_{s,b}]$$

$$V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.69 \text{ kip}$$

Considering x-direction:

$V_{max} = 18.853 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

$$\text{Ratio} = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(18.853 \text{ kip})}{(111.69 \text{ kip})}$$

$$Ratio = 0.1688$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$V_{max} = 0.042366 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.042366 \text{ kip})}{(111.69 \text{ kip})}$$

$$Ratio = 0.00037933$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 76.081 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(76.081 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.30481$$

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

Considering z-direction:

$M_{max} = 0.15788 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.15788 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00063254$$

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

REFERENCES	CALCULATIONS	RESULTS
------------	--------------	---------

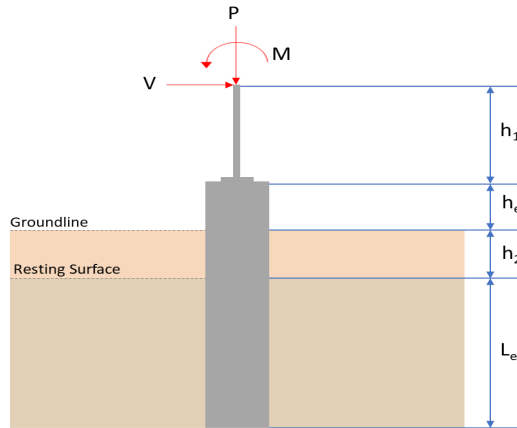
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.349	18.355
V_x (kip)	-4.935	-8.231
V_z (kip)	-0.026	-0.046
M_x (kipft)	-0.097	-0.171
M_z (kipft)	68.789	116.107

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.935 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.78583 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(68.789 \text{ kipft}) + ((-4.935 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.954 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.9457 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.097 \text{ kipft}) + ((-0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.015446 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.99617 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.9457 \text{ ft}), (0.99617 \text{ ft})]$$

$$L_{e,req} = 7.946 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.946 \text{ ft})}{(8.5 \text{ ft})}$$

$$\text{Ratio} = 0.93482$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(12.349 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.77181 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.77181 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.38591$$

Status: **PASS**
Ratio: **0.390**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.78583 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 10.954 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.954 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (10.954 \text{ kipft/ft})) + (4 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8714 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.954 \text{ kipft/ft})) + (3 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (10.954 \text{ kipft/ft})) + (2 \times (-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.3009 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (10.954 \text{ kipft/ft})) + ((-0.78583 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.2646 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8714 \text{ ft})}{2}$$

$$p_a = 0.44035 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.3009 \text{ kip/ft}^2)}{(0.44035 \text{ kip/ft}^2)}$$

$$Ratio = 0.68332$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.2646 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.99184$$

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

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = -0.0041401 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.015446 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015446 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.015446 \text{ kipft/ft})) + (4 \times (-0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0938 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.015446 \text{ kipft/ft})) + (3 \times (-0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (0.015446 \text{ kipft/ft})) + (2 \times (-0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = -0.00082785 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.015446 \text{ kipft/ft})) + ((-0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = -0.00035704 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0938 \text{ ft})}{2}$$

$$p_a = 0.45703 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.00082785 \text{ kip/ft}^2)}{(0.45703 \text{ kip/ft}^2)}$$

$$Ratio = -0.0018114$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

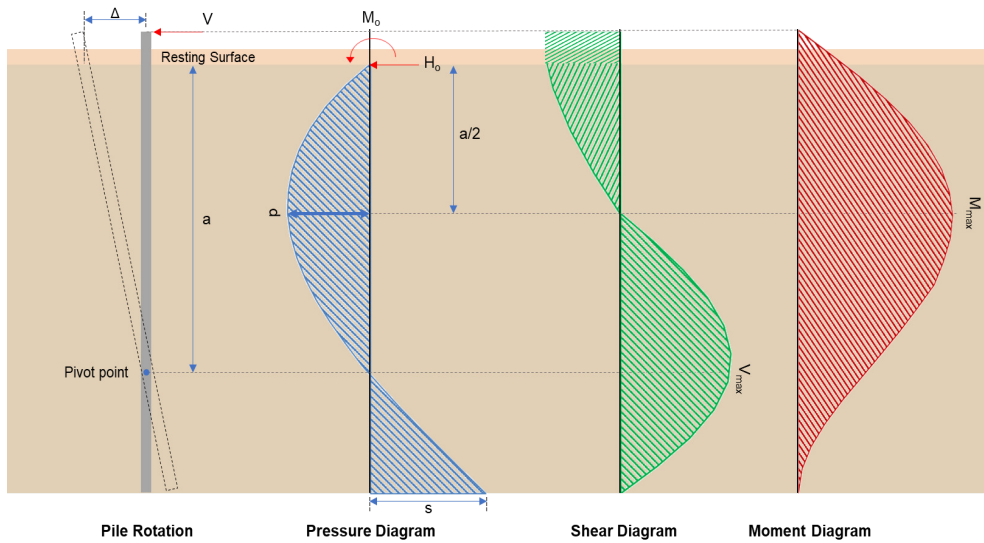
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(-0.00035704 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = -0.00028003$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.231 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.3107 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(116.11 \text{ kipft}) + ((-8.231 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 18.488 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.488 \text{ kipft/ft})}{(-1.3107 \text{ kip/ft})}$$

$$E = 14.106 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.488 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (18.488 \text{ kipft/ft})) + (4 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = \frac{(6 \times (18.488 \text{ kipft/ft})) + (4 \times (-1.3107 \text{ kip/ft}) \times (8.5 \text{ ft}))}{}$$

$$a = 5.8697 \text{ ft}$$

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

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

$$V_{max} = ((-1.3107 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8697 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8697 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 18.853 \text{ kip}$$

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

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

$$M_{max} = ((-1.3107 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(14.106 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8697 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8697 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (14.106 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8697 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 76.081 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.046 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0073248 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.171 \text{ kipft}) + ((-0.046 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.027229 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.027229 \text{ kipft/ft})}{(-0.0073248 \text{ kip/ft})}$$

$$E = 3.7174 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.027229 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.0073248 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.027229 \text{ kipft/ft})) + (4 \times (-0.0073248 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.0944 \text{ ft}$$

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

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

$$V_{max} = ((-0.0073248 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7174 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.0944 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (3.7174 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.0944 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.042235 \text{ kip}$$

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

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

$$M_{max} = ((-0.0073248 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(3.7174 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.0944 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (3.7174 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.0944 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.7174 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.0944 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.15733 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(18.355 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -83.986 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-83.986 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(18.355 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0068612$</p>	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.355 \text{ kip} \rightarrow 18355 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(18355 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.93 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.93 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.93 \text{ kip}$$

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

$$V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = \text{MIN}[V_{s,a}, V_{s,b}]$$

$$V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.69 \text{ kip}$$

Considering x-direction:

V_{max} = 18.853 kip - Maximum shear force in the x-direction,

Ratio - Capacity

$$\text{Ratio} = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(18.853 \text{ kip})}{(111.69 \text{ kip})}$$

$$Ratio = 0.1688$$

Status: **PASS**
Ratio: **0.170**

Considering z-direction:

$V_{max} = 0.042235 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.042235 \text{ kip})}{(111.69 \text{ kip})}$$

$$Ratio = 0.00037816$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 76.081 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(76.081 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.30481$$

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

Considering z-direction:

$M_{max} = 0.15733 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.15733 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00063032$$

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

REFERENCES	CALCULATIONS	RESULTS
------------	--------------	---------

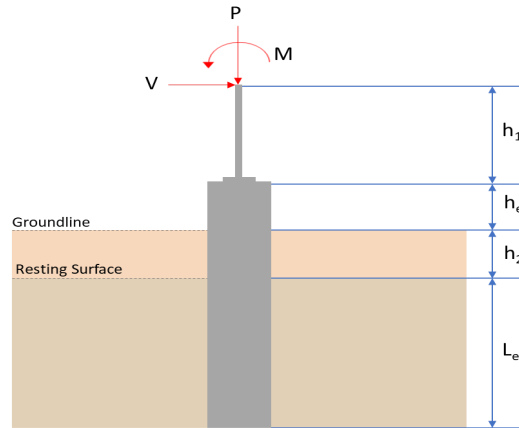
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.687	17.338
V_x (kip)	-4.712	-7.859
V_z (kip)	0.007	0.012
M_x (kipft)	0.019	0.034
M_z (kipft)	65.707	111.005

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.712 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.75032 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(65.707 \text{ kipft}) + ((-4.712 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.463 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.8495 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.007 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0011146 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.019 \text{ kipft}) + ((0.007 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0030255 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 0.65908 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.8495 \text{ ft}), (0.65908 \text{ ft})]$$

$$L_{e,req} = 7.85 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.5 \text{ ft}$$

Ratio - Embedded depth

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

$$Ratio = \frac{(7.85 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.92353$$

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

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

$$q = \frac{(11.687 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.73044 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.73044 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.36522$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.75032 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 10.463 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.463 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (10.463 \text{ kipft/ft})) + (4 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8713 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.463 \text{ kipft/ft})) + (3 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (10.463 \text{ kipft/ft})) + (2 \times (-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.28754 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (10.463 \text{ kipft/ft})) + ((-0.75032 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.2081 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8713 \text{ ft})}{2}$$

$$p_a = 0.44035 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.28754 \text{ kip/ft}^2)}{(0.44035 \text{ kip/ft}^2)}$$

$$Ratio = 0.65297$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(1.2081 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.94757$$

Status: **PASS**
Ratio: **0.650**

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

Considering z-direction:

$H_o = 0.0011146 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0030255 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0030255 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.0030255 \text{ kipft/ft})) + (4 \times (0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1456 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.0030255 \text{ kipft/ft})) + (3 \times (0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 [(3 \times (0.0030255 \text{ kipft/ft})) + (2 \times (0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.00060831 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0030255 \text{ kipft/ft})) + ((0.0011146 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 0.0012893 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.1456 \text{ ft})}{2}$$

$$p_a = 0.46092 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.00060831 \text{ kip/ft}^2)}{(0.46092 \text{ kip/ft}^2)}$$

$$Ratio = 0.0013198$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$

$$p_s = 1.275 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

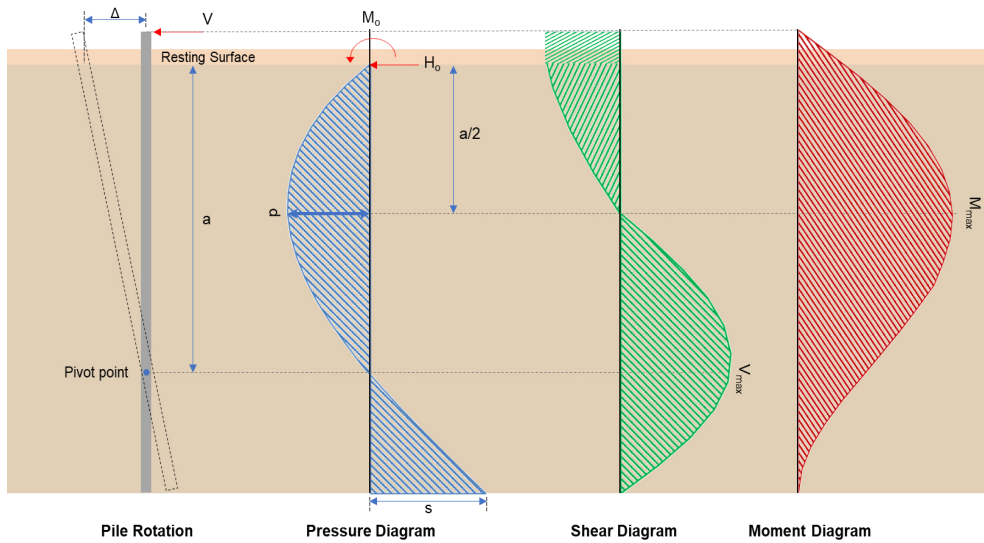
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0012893 \text{ kip/ft}^2)}{(1.275 \text{ kip/ft}^2)}$$

$$Ratio = 0.0010112$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.859 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.2514 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(111 \text{ kipft}) + ((-7.859 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 17.676 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(17.676 \text{ kipft/ft})}{(-1.2514 \text{ kip/ft})}$$

$$E = 14.125 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (17.676 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (-1.2514 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times 17.676) + (4 \times (-1.2514) \times 8.5)}$$

$$a = \frac{(6 \times (17.676 \text{ kipft/ft})) + (4 \times (-1.2514 \text{ kip/ft}) \times (8.5 \text{ ft}))}{}$$

$$a = 5.8695 \text{ ft}$$

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

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

$$V_{max} = ((-1.2514 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.125 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8695 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (14.125 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8695 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 18.02 \text{ kip}$$

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

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

$$M_{max} = ((-1.2514 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(14.125 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8695 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.125 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(5.8695 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (14.125 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(5.8695 \text{ ft})}{(2 \times (8.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 72.724 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.012 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0019108 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.034 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.005414 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.005414 \text{ kipft/ft})}{(0.0019108 \text{ kip/ft})}$$

$$E = 2.8333 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005414 \text{ kipft/ft}) \times (8.5 \text{ ft})) + (3 \times (0.0019108 \text{ kip/ft}) \times (8.5 \text{ ft})^2)}{(6 \times (0.005414 \text{ kipft/ft})) + (4 \times (0.0019108 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1389 \text{ ft}$$

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

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

$$V_{max} = ((0.0019108 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8333 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1389 \text{ ft})}{(8.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (2.8333 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1389 \text{ ft})}{(8.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.0096328 \text{ kip}$$

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

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

$$M_{max} = ((0.0019108 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(2.8333 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1389 \text{ ft})}{2 \times (8.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (2.8333 \text{ ft})}{(8.5 \text{ ft})} + 3 \right) \times \left(\frac{(6.1389 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.8333 \text{ ft})}{(8.5 \text{ ft})} + 2 \right) \times \left(\frac{(6.1389 \text{ ft})}{2 \times (8.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.035174 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\left(\frac{17.338 \text{ kip}}{(0.65) \times (0.8)} \right) - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.02 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.02 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(17.338 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0064811$	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.338 \text{ kip} \rightarrow 17338 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(17338 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.8 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (120.8 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.8 \text{ kip}$$

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

$$V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = \text{MIN} [V_{s,a}, V_{s,b}]$$

$$V_s = \text{MIN} [(737.28 \text{ kip}), (50.894 \text{ kip})]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.8 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.6 \text{ kip}$$

Considering x-direction:

V_{max} = 18.02 kip - Maximum shear force in the x-direction,

Ratio - Capacity

$$\text{Ratio} = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(18.02 \text{ kip})}{(111.6 \text{ kip})}$$

$$Ratio = 0.16147$$

Status: **PASS**
Ratio: **0.160**

Considering z-direction:

$V_{max} = 0.0096328 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

$$Ratio = \frac{V_{max}}{\phi V_n}$$

$$Ratio = \frac{(0.0096328 \text{ kip})}{(111.6 \text{ kip})}$$

$$Ratio = 0.000086316$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 72.724 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(72.724 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.29136$$

Status: **PASS**
Ratio: **0.290**

Considering z-direction:

$M_{max} = 0.035174 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.035174 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00014092$$

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

REFERENCES	CALCULATIONS	RESULTS
------------	--------------	---------

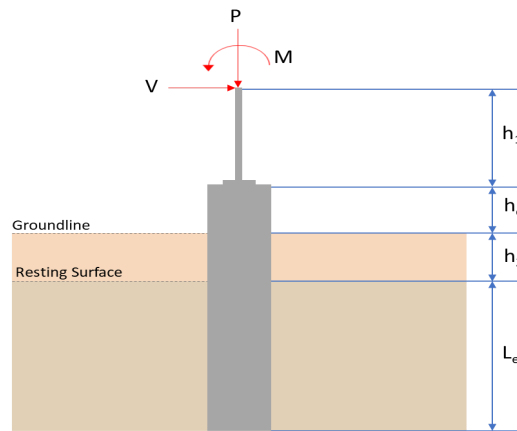
SkyCiv Foundation Design

Pile Foundation

Design Information :

Design code : IBC 2021 (International Building Code)
Unit System : Imperial

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 8.75$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.458	18.500
V_x (kip)	-5.013	-8.355
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	69.909	118.113

Material Properties

$f'_{ck} = 2.5$ ksi - Concrete strength.

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

$$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$$

$$H = 0 \text{ ft}$$

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.013 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.79825 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(69.91 \text{ kipft}) + ((-5.013 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.132 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 7.9808 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.9808 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 7.981 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.75 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.981 \text{ ft})}{(8.75 \text{ ft})}$$

$$\text{Ratio} = 0.91211$$

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

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

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

$$q = \frac{(12.458 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.77863 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.77863 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.38931$$

Status: **PASS**
Ratio: **0.390**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.1875$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.79825 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 11.132 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.132 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.79825 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (11.132 \text{ kipft/ft})) + (4 \times (-0.79825 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0484 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.132 \text{ kipft/ft})) + (3 \times (-0.79825 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (11.132 \text{ kipft/ft})) + (2 \times (-0.79825 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.28023 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (11.132 \text{ kipft/ft})) + ((-0.79825 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 1.1974 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0484 \text{ ft})}{2}$$

$$p_a = 0.45363 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.28023 \text{ kip/ft}^2)}{(0.45363 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.61775$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

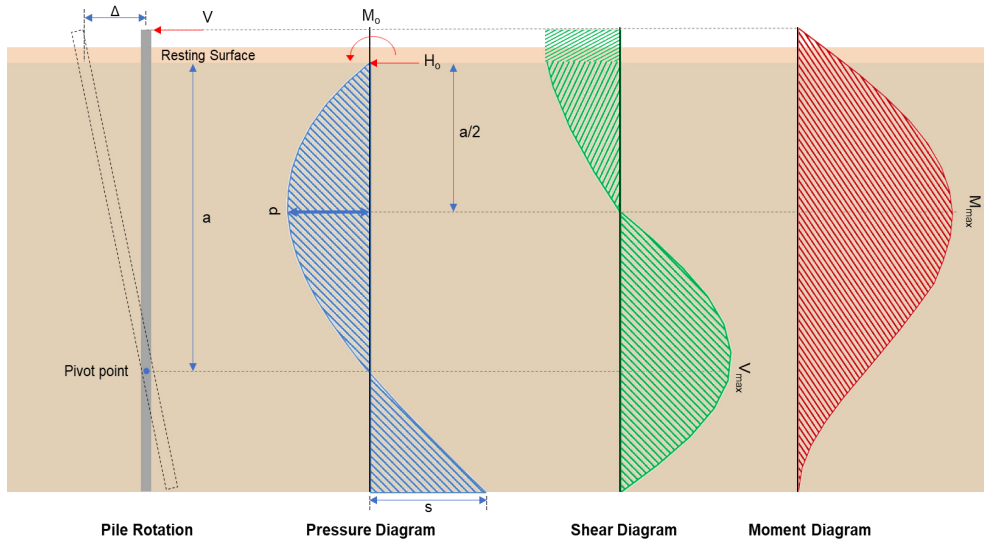
$$p_s = 1.3125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1974 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

Status: **PASS**
Ratio: **0.620**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.355 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.3304 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(118.11 \text{ kipft}) + ((-8.355 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 18.808 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.808 \text{ kipft/ft})}{(-1.3304 \text{ kip/ft})}$$

$$E = 14.137 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.808 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-1.3304 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (18.808 \text{ kipft/ft})) + (4 \times (-1.3304 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0463 \text{ ft}$$

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

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

$$V_{max} = ((-1.3304 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.137 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0463 \text{ ft})}{(8.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (14.137 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0463 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 15.125 \text{ kip}$$

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

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

$$M_{max} = ((-1.3304 \text{ kip/ft}) \times (48 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(14.137 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.0463 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.137 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0463 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (14.137 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0463 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 77.69 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(18.5 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -83.981 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-83.981 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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,

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

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$Ratio = \frac{(18.5 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0069154$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2 b_w = 48 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 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.5 \text{ kip} \rightarrow 18500 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18500 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.95 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (120.95 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 120.95 \text{ kip}$$

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

$$V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$$

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$

$$A_v = 0.11045 \text{ in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

$$V_s = \text{MIN}[V_{s,a}, V_{s,b}]$$

$$V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi (V_c + V_s)$$

$$\phi V_n = (0.65) \times ((120.95 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.7 \text{ kip}$$

Considering x-direction:

$V_{max} = 18.723 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

$$\text{Ratio} = \frac{V_{max}}{\phi V_n}$$

$$\text{Ratio} = \frac{(18.723 \text{ kip})}{(111.7 \text{ kip})}$$

$$\text{Ratio} = 0.16762$$

Status: **PASS**
 Ratio: **0.170**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 18432.001 \text{ in}^3$$

$$\phi M_{n,1} = 249.600 \text{ kipft}$$

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,

ϕM_n - Allowable flexural strength,

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

$$\phi M_n = \text{MIN}[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 77.69 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(77.69 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.31126$$

Status: **PASS**
Ratio: **0.310**